# MACHINIST'S MATE 1 & C

## NAVY TRAINING COURSES

NAVPERS 10525

# MACHINIST'S MATE

# 1 & C

**Prepared by**

U.S

**BUREAU OF NAVAL PERSONNEL**

NAVY TRAINING COURSES

NAVPERS 10525

UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON : 1955

# PREFACE

This training course has been written for Machinist's Mates 2 or 1 who are studying for advancement to the rate of Machinist's Mates 1 or C. Study of this training course should be combined with practical experience; with review of other applicable Navy Training Courses; and with study of manufacturers' instruction books, BuShips *Manual*, and other pertinent material.

Qualifications for advancement to the rates of Machinist's Mate 1 and C are listed in appendix II at the back of this publication. Since examinations for advancement are based upon those qualifications, it is suggested that you refer to them frequently for guidance.

This training course provides the Machinist's Mate with the information he will need in supervising the repair and overhaul of the main plant and auxiliary equipment. There are also two chapters on casualty and damage control—one dealing with damage control organization and supervision, the other dealing specifically with engineering casualty control.

In addition, there are four chapters on Navy repair procedures, material and supplies, records and reports, and trials and inspections. These subjects are discussed in considerable detail, because they are of great importance to the Machinist's Mate 1 or C as well as to other personnel of the Engineering Department.

As one of the Navy Training Courses, this publication has been prepared by the U. S. Navy Training Publications Center of the Bureau of Naval Personnel, with technical assistance rendered by the Bureau of Ships and by personnel of naval establishments specially cognizant of the Machinist's Mates duties.

# CREDITS

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# MACHINIST'S MATE

# 1 & C

# CHAPTER 1

# LEADERSHIP AND ORGANIZATION

## QUALIFICATIONS FOR ADVANCEMENT IN RATING

The requirements that you must meet before you can become a Machinist's Mate 1 or Chief are set forth in the *Manual of Qualifications for Advancement in Rating*, NavPers 18068 (Rev. 1952) ; for your convenience, they are listed in appendix II of this training course. Refer to these requirements and use them as a guide for study. The job for which you are now preparing requires technical knowledge, practical experience, and the ability to lead men. The MMC, and to a lesser extent the MM1, is a MASTER CRAFTSMAN, an INSTRUCTOR, a LEADER, a SUPERVISOR, and an INSPECTOR.

## SUPERVISORY AND ADMINISTRATIVE DUTIES OF MM1 AND C

Your primary job as a petty officer is to be a leader—to demonstrate those traits which make you effective in directing and handling other men. You won't find personnel relations listed in the qualifications for advancement in rating; however, it is this factor that will determine your success or failure as a Chief or First Class Petty Officer.

Supervising a group of men requires knowledge and skill. But these alone are not enough. Above all, supervision requires the tactful handling of the men assigned to you. Below are some fundamental principles which have been found successful in dealing with men. Study these principles carefully and apply them, in your thinking, to situations

that have occurred or are likely to occur. Then, in your dealings with the men assigned to you, try to apply the principles to the actual situations which you encounter.

### Fundamental Principles

KNOW YOUR MEN. Find out as much as you can about each of the men assigned to you. Each man is an individual and must be treated as such.

KEEP YOUR WORD. Men will respect you for doing what you say you will do.

KNOW YOUR OWN JOB THOROUGHLY. Know WHAT your responsibilities are and just how far your authority extends. Know HOW to perform the technical skills your rating calls for. The more familiar you are with the equipment and skills available to you, the better able you will be to coordinate your work with the work of others in the engineering group.

KNOW HOW TO GIVE ORDERS. The secret of giving a good order is to make it mean business. If you act as though you expect the job to be done well, it will be. A good order clarifies (1) WHAT is to be done, (2) WHEN it is to be done, (3) HOW it is to be accomplished (if instructions are necessary), and (4) WHY it must be done (when practicable to explain).

REPRIMAND IN PRIVATE; PRAISE IN PUBLIC. Never "bawl a man out" in front of his shipmates—the purpose of a reprimand is to teach, not to embarrass. Always be sure your criticism is constructive. Praise a job that is well done, and, if possible, give your commendation in public. Men do better work if they know their efforts are appreciated.

KEEP YOUR MEN INFORMED. Whenever possible, let your men know the purpose of their jobs. If they realize that what they are doing is important, they will do better work.

CONSIDER THE SAFETY OF YOUR MEN AT ALL TIMES. Throughout the naval service you will find safety precautions pertaining to daily routine. ALWAYS OBSERVE THESE SAFETY PRECAUTIONS and see that your men observe them—don't permit them to take unnecessary risks.

Take an Interest in the Personal Problems of Your Men. Let your men know by your actions that you are looking out for their interests at all times.

*The General Training Course for Petty Officers*, NavPers 10055, and *Human Behavior and Leadership*, NavPers 10058, will give you more detailed information on leadership. If you have not already become acquainted with these *Manuals*, do so at once; you will find them invaluable in helping you to become a good leader. You should also refer to the monthly *U. S. Navy Training Bulletin*, NavPers 14976, which deals extensively with methods of supervising naval personnel.

## Effective Supervision

There are many skilled workmen, thoroughly familiar with every phase of their specialty, who cannot supervise the work of others. Supervision is a job in itself and you must learn how to do it.

When you're in charge of a detail, you'll supervise lower-rated men and strikers. It will be necessary for you to assign work to these men and to see that it is properly completed. Of course, it is not necessary, or desirable, to be "breathing down a man's collar" while he is trying to perform a task, but you must be on hand to see that things go right and to give advice when it is needed.

Good supervision may be achieved by observing the following steps:

1. Plan the job thoroughly, so that you know exactly what is to be done and, as far as possible, how you are going to meet the problems which are likely to arise.

2. Explain the assignment clearly enough so that the individual who is going to do the job understands just what is to be done.

3. Check the progress of the job, particularly in the early stages, to catch mistakes before they can result in excessive loss of time, labor, and material.

4. Suggest methods for doing the job, but allow the man to select any method which will result in a job well done.

5. ENCOURAGE quality in all work.

6. INSPECT each job, taking care to point out methods and reasons for eliminating unsatisfactory finished products. Be sure to give recognition and credit to outstanding work.

7. INSIST on the use of manufacturers' instruction books and applicable blueprints.

## Instruction

One of your primary duties as MM1 or MMC will be to instruct your men in the performance both of their technical jobs and of their military duties. The fundamental principles of leadership, of course, apply to the teaching-learning situation as much as to any other situation in which you are dealing with men. Instructing is a very complex skill, and you will have to train yourself to be an effective teacher. The following suggestions will help you:

1. KNOW YOUR SUBJECT. In order to be able to explain the subject matter which you are teaching, you must be thoroughly familiar with it.

2. PLAN THE LESSON. You must decide exactly what you want to teach—what knowledge or skill you wish your students to learn. Then you must plan how you are going to impart this knowledge to others, what questions you are going to ask, and what training aids you will use.

3. MAKE THE TASKS MEANINGFUL. This can be accomplished by tying new material in with what the student already knows, and by showing the student how the new material relates to his particular duties.

4. REGULATE THE SIZE OF THE TASK. No one can be expected to learn a lengthy and complicated task all at once. Your problem as an instructor is to break down such a task into component parts which are meaningful units of work. (If a job logically falls into four stages, breaking it down into five or six will increase, rather than decrease, the difficulty of learning.)

5. HAVE YOUR MEN PARTICIPATE. Watching someone do a repair job will help a little, but we do not really learn

how to do a job until we have actually performed it. See that your men spend as much time as possible working on a skilled task, and as little as possible in listening to explanations and watching demonstrations.

6. USE MORE THAN WORDS. To supplement oral descriptions in the classroom, you should use charts, diagrams, training films, working models, and slides. In on-the-job training you will, of course, have the actual equipment on which to demonstrate.

7. REPEAT AND DRILL. Complex acts and skills are not learned without repetition. Drill, however, should be used wisely. It should be spaced so as to avoid monotony and fatigue. Several short periods of drill, spaced over a period of time, are better than one long period.

8. LET THE STUDENT KNOW HE IS PROGRESSING. The student must not only have a clear picture of what he is aiming at in the way of knowledge or performance, but he must also know how well he is progressing.

9. USE MUCH REWARD, LITTLE PUNISHMENT. Correct response should be amply rewarded; incorrect responses are better rectified by calling attention to the right response than by punishment. In a few cases and for a few people, of course, punishment is necessary; but, in general, praise for good work gets better results than blame for poor work.

Although much of your instruction will be in the form of actual practice, you will be expected also to lead discussions, deliver lectures, and give demonstrations. If it is consistent with the work to be performed, keep adding new and unfamiliar tasks to the regular duties of your men. You will then have to teach the men the proper way to perform their newly assigned duties. Thus, the men's knowledge of their trade is broadened and your teaching ability is improved.

## SHIP ORGANIZATION

A ship's organization bill, which delegates authority and fixes responsibility, is written before a ship is placed in commission. All naval vessels conform to the same general

organizational pattern, but the details of the pattern vary somewhat from ship to ship. One of the first things you should do when you report aboard is to familiarize yourself with the organization of your ship, your department, and your division.

In order to carry out your new duties as a supervisor, you must be familiar with the Ship's Organization Book and Ship's Orders, and with the Engineering Department organization and standing orders. As a First Class or Chief Petty Officer aboard ship, you'll assist a division officer in organizing, supervising, and instructing other men in their military duties as well as in their specialities. Therefore, you'll need to be familiar with the organization of the Engineering Department. It will be your duty to support this organization and see that rules and regulations are properly enforced.

## ENGINEERING DEPARTMENT WATCHES

Every watch in the Engineering Department is a vital function of the ship's maintenance and operation program. The engineer officer is responsible for the operation and maintenance of the main engines and auxiliary machinery. However, the Machinist's Mates 1 and C, and the men they supervise on the various watches, will actually do most of the work. Therefore, it is very important that the CPO in charge understand the extent of his responsibility to the engineer officer.

### Engineering Officer of the Watch

The following articles from *Navy Regulations* (chapter 10) will give you a general idea of the duties of the officers of the engineroom watch:

> ***Status, Authority, and Responsibility.***—The engineering officer of the watch is the officer on watch in charge of the main propulsion plant of the ship, and of the associated auxiliaries. He shall be responsible for the safe and proper operation of such units, and for the performance of the duties prescribed in these regulations and by other competent authority.

*Directing and Relieving the Engineering Officer of the Watch.*—The engineer officer, or, in his absence, the main propulsion assistant may direct the engineering officer of the watch concerning the duties of the watch, or may assume charge of the watch and shall do so should it in his judgment be necessary.

*Relation with the Officer of the Deck.*—The engineering officer of the watch shall insure that all orders received from the officer of the deck are promptly and properly executed. He shall not permit the main engines to be turned except as authorized or ordered by the officer of the deck.

*Reports by the Engineering Officer of the Watch.*—The engineering officer of the watch shall report promptly to the officer of the deck and the engineer officer any actual or probable derangement of machinery, boilers, or auxiliaries which may affect the proper operation of the ship.

*Reports to the Engineering Officer of the Watch.*—The engineering officer of the watch shall be promptly informed of any engineering work or change in disposition of machinery which may affect the proper operation of the plant or endanger personnel, or which is required for entry in the record of his watch.

*Inspection and Operation of Machinery.*—The engineering officer of the watch shall cause frequent inspections to be made of the engines, boilers, and their auxiliaries; and shall insure that prescribed tests, methods of operation, and instructions pertaining to the safety of personnel and material are strictly observed.

*Records and Logs.*—The engineering officer of the watch shall insure that the engineering log, engineer's bell book, and prescribed operating records are properly kept. On being relieved, he shall sign the engineering log and the engineer's bell book for his watch.

## Watch, Quarter, and Station Bill

As an MMC, you will assist your division officer in maintaining the Watch, Quarter, and Station Bill and in assigning watch stations and duties to all individuals in the division. After an individual has been interviewed and has furnished you with information concerning his background, you can recommend the billet where his past experience and training will be most effective. Because of rotation of personnel, the Watch, Quarter, and Station Bill requires constant revision.

As a watch stander, you will be the eyes of the Engineering Department. You will be responsible for the orderly appearance and cleanliness of your assigned station. Prior to standing watch, you should thoroughly inspect all existing conditions, such as the operating condition of machinery and fire-fighting equipment. You should also check the assigned area for leaks and potential fire hazards. If a casualty occurs, you should take immediate steps to control it, and should notify the proper authority.

While on watch, you should strictly observe all operating instructions, regulations, and safety precautions. You should never leave your station unless you have permission from proper authority to do so, or are properly relieved. You should promptly execute all standing or special orders. When relieved, you should pass on to the relieving watch all information concerning existing conditions and special orders.

There are several watches that you may stand or be responsible for; the stations and duties of these watches are discussed in the following section, to guide you in qualifying yourself and the men who may serve under your supervision. However, Machinist's Mates 1 and C should have complete knowledge of the details of all watches to be stood. This chapter makes no attempt to describe the various watches in detail, and those watches which do not apply to all ships are omitted.

THE CPO IN CHARGE OF AN ENGINEROOM WATCH, while the ship is under way, should have a general knowledge of the capabilities of the men assigned to the watch detail. In order to determine whether or not a man fully knows his job as a watch stander, the CPO should, as soon as practicable, check on or interview new men assigned to his watch. Additional instruction, as found necessary, should be given to each watch stander.

The MMC should know all engineering casualty control procedures for the engineering plant of his ship. This in-

cludes casualty procedures for engineroom, for fireroom, and for ship's service turbogenerators; in addition. the MMC should know how to deal with any casualty which could affect the operation of the propulsion plant.

It is advisable that the CPO, while on engineroom watch, take advantage of slack periods to make sure that all men assigned to the watch have the necessary knowledge and ability for the various engineering casualty drills.

Remember that even in a short time an inexperienced man can learn a great deal, including the correct methods for performing his job as a watch stander, from an experienced chief or first class petty officer who is a good instructor.

Under the direction of the engineering officer of the watch, the MMC is usually in charge of the engineroom watch. He sees that all machinery and equipment are operating properly and that all engineroom stations are properly manned. He checks all bearing temperatures and observes which boilers are steaming and which fuel oil and feed water suctions are in use. He checks the engineroom log and the bell book for entries and signature.

While the MMC is on watch, he makes certain that the men under his supervision are alert and attending strictly to their duties, and that temperatures, pressures, and vacuums are being maintained as required. He must see that all signals from the bridge are answered, and orders promptly enforced. He checks the lube oil gages frequently. He enforces all pertinent safety regulations and is responsible for complete and accurate entries in both the engineer's bell book and the engineroom log. He keeps the engineer officer of the watch informed on all engineroom operations.

The THROTTLEMAN, usually an experienced man, must adjust throttle valves quickly and accurately in order to comply with the speed signals from the bridge. He makes an entry in the engineer's bell book for every signal received from the bridge. He must be thoroughly familiar with the operation and functions of throttle valves, and with all engineering casualty control procedures and safety precautions concerning main engines and vital auxiliaries.

The PUMPMAN, usually the lower-level watch, must know the function, construction, and operating principles of the pumps and other machinery and equipment on his station. He should be able to start, operate, and stop all pumps and equipment on his station, and to keep this machinery operating smoothly at all times. To do this requires that he make frequent inspections of all machinery, and see that moving parts are properly lubricated and receive cooling water. He is particularly concerned with the main feed and lubricating oil pumps. He also checks closely the fire, flushing, and cooling water circulating pumps. He keeps standby pumps warmed up at all times and reports unusual occurrences to the MMC of the watch. The pumpman should observe applicable regulations and safety precautions, and should be capable of handling machinery casualties that may occur on his watch station.

The MESSENGER of the watch assists in taking engineroom log readings, calls the relieving watch, dumps trash, and checks bearings for oil leaks. He is responsible for maintaining the proper oil level in the bearing sumps, and for checking for foreign matter in the lubricating oil. He informs the CPO in charge of the watch if any bearing is not receiving sufficient oil, or shows signs of heating. If qualified, he may serve as the JV phone talker.

### In-Port Watches

CPO-DAY'S DUTY. When the ship is not under way, CPO's stand a 24-hour watch duty in rotation, usually from 0800 to 0800, or from 1100 to 1100. The watch is turned over to the relief at either the log room or the control engineroom. At that time the parties concerned exchange all necessary information.

The duty CPO has a job similar to that of the engineering officer of the watch, with the exceptions that he has a 24-hour duty, the ship is not under way, and the duty headquarters is the log room. The duty CPO also maintains the engineering log entries, and keeps the duty engineering officer constantly informed of any unusual existing conditions.

Generally, the CPO on the day's duty is furnished with the necessary information concerning the lighting off, getting under way, the time stations are to be manned, and the duty sections that are to man the stations.

Before the time scheduled for the ship to get under way, the engineering duty officer checks the lighting-off sheets, steaming orders, and any special instructions which are to be carried out. When the engines are to be tested, the engineering duty officer gets permission from the officer of the deck to conduct the tests.

ENGINEROOM AUXILIARY WATCH.—Auxiliary watches are maintained under way and in port, to supply the light, power, steam and other services to make the ship livable. The engineroom auxiliary watch in port consists of a Machinist's Mate in charge of one or more Firemen. The MM is responsible for seeing that an efficient and economical watch is being stood. All machinery not in operation must be checked to see that it has been properly secured.

The MM in charge of the auxiliary watch is responsible for the proper operation of the ship's service turbogenerator and associated machinery; however, an electrician's mate will be responsible for the operation of the electrical equipment. The MM sees that the water in the auxiliary condenser is tested every 30 minutes and that the chloride content is not allowed to exceed 0.1 epm. The water in the deaerating feed tank must be maintained at the prescribed level and temperature, and should be tested for chloride at least once each watch. The MM in charge must see that all operating machinery is lubricated as prescribed by the operating instructions. He should see that the fire and flushing pumps are inspected for satisfactory operation and that the prescribed pressure is maintained on the firemain.

Except in emergencies, the engineroom auxiliary watch does not make any changes such as stopping, starting, or shifting ship's service generators without first notifying the Chief Electrician's Mate and the Chief Machinist's Mate.

A watch going off duty will not be considered relieved

until the floor plates are wiped, the engineroom is clean, and information concerning the status of the machinery in operation, orders, special orders, and uncompleted orders has been given to the relief.

The forenoon watch carries out the following daily routine, unless otherwise instructed:

1. Moves by hand all auxiliary machinery not in use
2. Runs the lubricating pump and tests standby pumps
3. Jacks over the main engines
4. Makes an entry in the engineering log to show that the items in the daily routine have been carried out

On Fridays, in addition to the daily routine, the forenoon watch usually carriers out the following routine and makes the appropriate entries in the engineering log:

1. Operates and tests all safety appliances and fire-fighting equipment
2. Checks lubricating oil in all machinery for water and for condition of oil
3. Lifts all relief valves by hand
4. Checks the operation of all valves

COLD-*I*RON WATCHES. Under certain prescribed conditions (such as when a ship moves alongside a repair ship or tender, or into a naval shipyard, and is receiving power from these activities) a security and fire watch is usually set by each division. This security watch is commonly known as a cold-iron watch. Each cold-iron watch makes frequent inspections of the assigned area and is on the lookout for fire hazards, flooding, or other unusual conditions throughout the area. The cold-iron watch keeps bilges reasonably free of water in accordance with any harbor pollution regulations. Hourly reports on existing conditions are made to the officer of the deck.

Any UNUSUAL existing conditions are immediately reported to the officer of the deck and to the engineering duty officer, so that the proper division or department can be notified to take necessary corrective measures. In case welding or burning is to be performed in the area, the cold-iron watch checks to see that a fire watch is stationed.

If the ship is in drydock the watch must check all sea valves after working hours, to see that the valves are secure or blanked off. Oil, or water containing oil, should not be pumped into the drydock at any time. Weights such as fuel oil, feed water, or potable water should not be shifted without permission of the engineer officer.

### Fireroom Watches

THE CPO IN CHARGE of the fireroom must not only know what is required of the boilers, but he must also know the conditions existing within them. When only one fireroom is in operation, the CPO in charge is usually told to keep the steam pressure at a given point, but the control of the blowers, the air pressure, the number of burners, and other details are left to his judgment. When the ship is steaming with boilers in two or more firerooms, a carefully planned system for controlling the rate of combustion in each boiler is essential. Such a system is discussed in the Navy Training Course, *Boilerman 1 and Chief*, NavPers 10536–A.

The CHECKMAN assigned the duty of maintaining the predetermined water level in the boiler must be thoroughly qualified for that duty, and should have no additional duties. Except for momentary fluctuations during maneuvering, the designated water level should be maintained under all steaming conditions. Maintaining the apparent water level constant under all conditions is the criterion of efficient water tending and requires constant vigilance. The checkman should know the correct procedures for the high-water and the low-water casualties.

The BURNERMAN maintains the correct steam pressure by cutting in or cutting out burners or by regulating the fuel oil pressure at the burners. Steam pressure should be held as steady as possible. The burnerman must constantly check for dirty atomizers and change them when authorized by the CPO in charge of the watch. On small ships, such as destroyers, the burnerman at the boiler must depend on both the boiler steam-pressure gage and the superheater steam

thermometer for information on conditions within the boiler. As the steam conditions change, the burnerman rapidly cuts burners in or out as required, in order to maintain steam pressure and temperature as constant as possible. The burnerman should have no other duty to distract him while the ship is maneuvering.

The BLOWERMAN maintains the air pressure in accordance with the number of burners, size of sprayer plates, and the oil pressure carried. Every effort should be made to operate with the lowest possible air pressure in order to permit smokeless operation (or to give a light-brown haze, if so directed, for the sake of economy). The blowerman must remember that a corresponding increase in air pressure should always precede an increase in the rate of combustion, and a decrease in the air pressure should always follow a decrease in the rate of combustion.

The PUMPMAN helps keep fuel oil supply pressures and oil temperatures at prescribed levels. He must be qualified to start and stop all machinery in the fireroom, cut in or cut out fuel oil heaters, and shift fuel oil strainers. He sees that both the emergency feed and the standby fuel oil service pumps are warmed up and ready for use. He should know how to cut in and cut out the main feed and fuel oil systems. In addition, he checks the auxiliary machinery carefully in order to see that this machinery operates efficiently.

The MESSENGER of the watch keeps the fireroom swept down, wipes up oil, assists in the cleaning of burners, takes log readings, calls the relieving watch, acts as JV talker (if qualified), and in general is the handy man in the fireroom. However, it should be borne in mind that the messenger is expected at the same time to be qualifying for other duties in the fireroom.

## SUMMARY

Leadership will now play a more important part in your duties. Now that you have learned to run machinery and have become proficient in its operation and maintenance,

*you* will be called upon to impart your knowledge to lower-rated men and strikers.

Leadership requires that you know your job, your ship, and above all, your men. What seems elementary to you might not be to a man new to the Navy. You must not only help him to become adjusted, but also teach him his job, and instruct him in his responsibilities. In addition, you must see that he carries out his duties properly, and you must explain the relationship of his job to the over-all operation of the engineering plant.

There are many Navy publications which will assist you in mastering principles and techniques of leadership. You will find that leadership is something that you will have to work at. Proper supervision will have an important bearing on the attitudes of your men and the quality of their work.

## QUIZ

1. The requirements that you must meet before you can become a Machinist's Mate 1 or C are set forth in which publication?
2. What factor will determine your success or failure as a chief or first class petty officer?
3. What is your primary job as a petty officer?
4. What 3 factors are required for good supervision?
5. What 4 factors constitute a good order?
6. In supervising a job, why should you check the progress of the job in the early stages?
7. To supplement oral descriptions in the classroom, what should you use in teaching your men?
8. When you report aboard ship as a CPO, what should you familiarize yourself with?
9. Who authorizes the engineering officer of the watch to have the main engines turned?
10. To whom does the engineering officer of the watch report any actual or probable machinery derangements?
11. Information concerning the watches and stations which are to be manned, in all readiness conditions, can be found in which publication?
12. Who is usually in charge of the engineroom watch, under the direction of the engineering officer of the watch?
13. How often should the water in the auxiliary condenser be tested, and by whom?
14. Upon being relieved, what information should the petty officer of the engineroom auxiliary watch turn over to his relief?
15. How frequently is all auxiliary machinery moved by power when the machinery is not in operation?
16. When a ship is receiving power from a repair activity, what type of watch is usually set by the Engineering Department?
17. What is the duty of the checkman assigned to a fireroom watch?
18. What 3 factors govern the air pressure maintained by the blowerman?
19. Who helps keep the fuel oil supply pressure at the pressure specified and the oil temperature as directed?
20. Who takes log readings of the fireroom watch?

# CHAPTER 2

## PROPULSION TURBINES

The main turbines, reduction gears, and boilers constitute the major units of the ship's propulsion plant—the most important of all the machinery on board ship. Malfunctioning of this machinery or damage to any of the parts can necessitate repairs which may be costly, and will usually require the facilities of a shipyard. If a ship is to be ready at all times for unlimited operations, the main units of the propulsion machinery, such as turbines, must constantly receive the best of care in operation, maintenance, and repairs.

This chapter will present selected information on operation, maintenance, and repairs of the most common types of main turbines. The MM1 or C should refer to the chapter on turbines in BuShips *Manual* in order to obtain information beyond the scope of this training course. The detailed information necessary for shipboard maintenance and repair of turbines is obtainable from the manufacturer's instruction book, and from blueprints.

### TURBINE OPERATION

There are two common types of main turbine installations on naval ships. Differences between the two types depend on whether or not a cruising turbine is provided.

The type of turbine installation on destroyers (and some other ships) consists of three units: the high-pressure, low-pressure, and cruising turbines. The astern turbine is designed and built as part of the low-pressure turbine. Figure

2–1 shows an example of one type of installation of main turbine and reduction gears. For different types of ships that have this type of propulsion plant, the size of the turbine and the construction of the gears will vary.

In order to obtain maximum economy and efficiency of operation, cruising stages are provided in turbine installations which do not have a cruising turbine. These turbine installations are designed for good operating economy at cruising speeds as well as at full power. This economy is obtained by the use of 6 or 7 nozzle control valves. These nozzle control valves, similar to other turbine installations, are operated by a single handwheel at the main throttle board. As more steam is admitted to the turbine, the individual valves are opened in a predetermined sequence.

## Lubrication of Turbines

One of the important factors in the operation and maintenance of main turbines is an adequate supply of lubricating oil having the correct physical and chemical qualities. Most turbines are provided with needle valves that permit adjustment of the oil flow to all journal and thrust bearings. The needle valves and orifices at the various turbine bearings require a high-grade mineral oil (Navy Symbol 2190T) with a pressure of 10 psi at the needle valves. They are adjusted so that the temperature rise of the oil through the bearings is about 25° F at full power. The midpoint setting of a needle valve is correct for normal operating conditions. Normally the setting of these needle valves should not be disturbed or readjusted except by experienced maintenance personnel.

In case of an overheated bearing, the flow of oil should be increased by opening the needle valve. When corrections or repairs have been made, the needle valve setting should be adjusted to its normal position. Although the flow of oil through a needle valve cannot be shut off entirely, the flow should not be reduced below the normal amount.

There is a possibility that over a period of years a needle

valve, with a normal setting, may allow a bearing to be supplied with so much oil that leakage from the ends of the bearing occurs. In such a case, if repairs to the needle valve are not practicable, the regular setting of the needle valve should be reduced until a normal flow of oil through the bearing is established.

For most main turbines, the normal operation of the inlet oil temperature should be between 120° and 130° F and at full power the outlet oil temperature should be between 140°

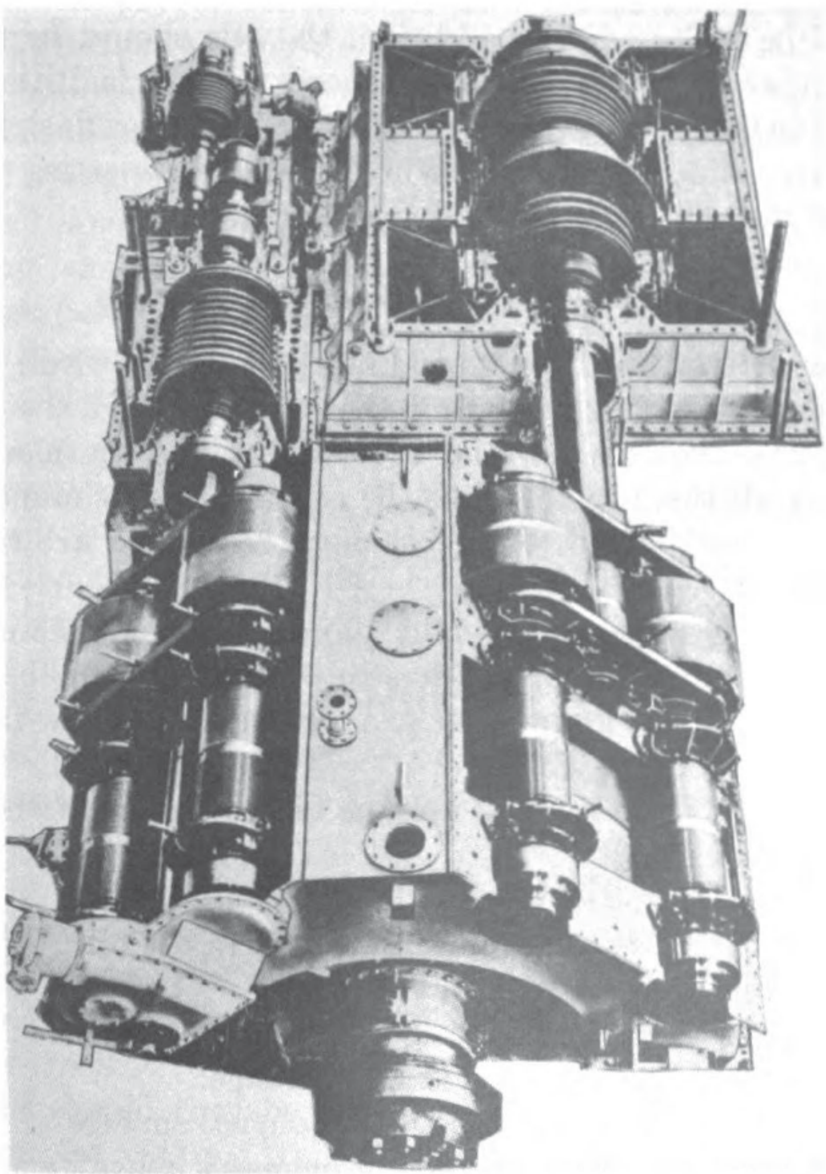


Figure 2–1.—Steam turbine and reduction gear with casings removed.

and 160° F. The maximum temperature rise of oil passing through any bearing under any operating condition should not exceed 50° F, nor should the final temperature of the outgoing oil exceed 180° F. Cooling water should be turned on when the temperature of the oil leaving the main lubricating oil cooler reaches 120° F.

The lubricating oil should be maintained free from water and impurities by means of the oil purifier and the settling tank. In keeping a continuous check on the condition of the lubricating oil, a routine procedure of taking oil samples should be followed. In addition, the oils should be tested at regular intervals whenever shore testing facilities are available to determine the neutralization number, flash point, viscosity, and other physical or chemical properties which govern the effectiveness of oil as a lubricant.

### Procedure When a Bearing Overheats

Bearing temperatures depend on the viscosity of oil being used, the design of the bearing, the running speed, the clearances, and the location and accuracy of the thermometer. Because all these factors must be considered, optimum temperatures applicable to all bearings cannot be arbitrarily established.

Operating personnel should thoroughly understand the precautions and the procedures to prevent possible bearing troubles, and also know what procedure(s) to follow in case bearing troubles occur.

Generally a hot bearing may be traced to one of the following causes:

1. Improper or insufficient lubrication.
2. Grit, dirt, or other foreign matter in the oil.
3. Bearing out of line.
4. Bearing improperly fitted.
5. Obstruction in the oil line or passage.
6. Poor condition of bearing or journal surface.

If the temperature of a bearing increases above its normal running temperature, the quality and quantity of the oil to

that bearing should be checked immediately. If the bearing has not been wiped, the supply of oil to the bearing may be increased by opening the needle valve in the oil supply line or passage to the bearing.

When below normal pressure, the delivery pressure of the oil pumps should be increased. The oil should be further cooled by increasing the flow of circulating water to the oil cooler in case the temperature of the oil from the cooler is above the normal temperature. If the bearing is hot because of improper lubrication, an abundant supply of oil should gradually bring the bearing back to its normal operating temperature. An increased supply of oil may also flush out impurities in the bearing sufficiently to permit continued operation.

If a bearing is out of line or improperly fitted, or if the bearing and journal surfaces are not in good condition, only temporary relief can be looked for by use of the various means suggested above. If the above measures are not effective, the speed of the turbine should be reduced; when necessary, the turbine should be immediately slowed down and stopped. The use of water on a bearing should not be resorted to except in a case of emergency, as cold water causes contraction of the bearing, further reducing the clearance.

The most effective treatment of a hot bearing will probably be the operation of the turbine at low or moderate powers until such time as the proper inspections and repairs can be made. Usually an abnormal temperature in a bearing can be lowered by decreasing the amount of work of the bearing. Care should be taken to avoid allowing the temperature to exceed the safe bearing temperature; bearing metal becomes soft when its critical temperature is reached.

When hot bearing conditions become critical, the turbine should be immediately slowed down, if practicable. The turbine should then be rolled over at a minimum speed to prevent the bearing from freezing. After the bearing has cooled sufficiently, the turbine should be stopped and the main shaft locked, with the lubrication system in operation.

Bearing depth gage readings should be taken to determine if any wear of the bearing has occurred. If no wear of the bearing has occurred, operation of the turbine at low speeds can again be attempted, or the bearing can be disassembled for a complete inspection. In case the bearing readings show that abnormal wear or wiping of the bearing has occurred, the bearing must be disassembled for repairs. Operation of wiped bearings will cause serious damage to the turbine.

In case of a hot bearing, the lubricating oil should be carefully inspected and renovated as found or considered necessary. Additional information on bearings and lubricating oil system casualties is given in other chapters of this training course.

### Astern Power Limitations

The MM1 or C must be familiar with astern power limitations for his ship. Each ship has its own designed operating requirements for maximum astern power. Additional information concerning astern power limitations for the ship is given in chapter 41 (article 131), of BuShips *Manual*.

It is important that vacuum be maintained at the best obtainable value during all astern operations. During long runs at high power astern, all thermometers indicating turbine-casing temperature should be carefully observed. An excessive temperature rise should be taken as a warning to reduce the ship's astern speed. Excessive temperatures may be caused by (1) failure to observe astern speed limitations, or (2) leakage ahead of the nozzle control valves. If there are indications that control valves are leaking, the valves should be checked for tightness as soon as possible.

### Abnormal Operating Noise or Vibration

Freedom from vibration is essential to the efficient operation of turbines. If an abnormal noise or vibration is encountered while a turbine is in operation, the cause may be due to any one or a combination of the following troubles:

1. Water in the turbine.

2. Bearing troubles.
3. Rubbing of packing or oil seal rings.
4. Rubbing of turbine blading.
5. Damaged or broken blading.
6. Bent or broken propeller blades.

Vibration accompanied by a rumbling noise probably indicates the presence of water in the turbine casing, either from boiler priming or inadequate casing drainage. In either case the throttle should be closed immediately and the shaft stopped. When the high water casualty has been corrected (and the main steam line drained) or the turbine casing properly drained, the turbine may be placed back into operation, unless there still is an unusual noise or vibration, because of damage done by the water.

When bearing troubles occur, the turbine should be stopped as soon as practicable to prevent damage to the turbine. An investigation should be made to determine the condition of the bearing. Bearings should be reconditioned or replaced as found necessary. The cause of the trouble should be determined and measures taken to prevent any similar troubles from recurring.

Rubbing of labyrinth (or carbon) packing or oil seal rings is usually caused by one of the following: bad bearings, bowed rotor, or (in rare cases) improper installation of packing or seal rings. The turbine shaft will overheat due to friction and may start to show heating colors. The turbine should be stopped to prevent any possible damage to the turbine blading. An inspection should be made to locate the cause of the trouble. If defective bearings are located, they should be replaced. A bowed rotor should be straightened out by operating it at a low speed until all parts have expanded equally. The shaft packing or oil seal rings may need to be refitted or replaced to give proper allowance.

When rubbing of turbine blading occurs, the cause will probably be a bowed rotor, a defective thrust bearing, burned out journal bearings, or foreign material inside the turbine casing. The turbine should be stopped immediately and the cause of the trouble determined. (If the turbine has just

been started, the trouble may be a bowed rotor. Foreign matter in a turbine cannot be readily determined unless a defective main steam strainer has been found.)

A rubbing noise in the turbine, followed by a sharp, metallic sound, is an indication that part of the blading has been damaged. The turbine should be shut down and not used until the extent of damage has been ascertained and repairs made. All pertinent information on the casualty should be written up in the engineering log. The investigation and repairs will normally be made by a repair activity.

Another cause of vibration and noise in a main turbine may be bent or broken propeller blades. Normally, this condition is first indicated by the excessive vibration of the main shaft together with the abnormal noise and the vibration of the main reduction gear. When these other conditions are present, it may be assumed that the vibration and noise are caused by the main shaft or propeller. The main shaft should be slowed down until the vibration stops or is within safe limits. An inspection should include the spring bearings, stern tube bearing, bulkhead stuffing tubes, and shaft couplings. If these are found to be in good condition, it may be assumed that the trouble is outside the ship. It may be that a line or cable has fouled the propeller. In this case the ship may be backed in an attempt to free the propeller. If there are no indications of a fouled propeller, it may be assumed that the propeller has been damaged. This may be substantiated by other conditions, such as operating the ship in shallow water. When conditions permit, the services of a diver should be obtained to inspect the propeller.

### Rotor Balance

The turbine rotors are carefully balanced both statically and dynamically. If, under rare circumstances, a rotor becomes unbalanced, it will be necessary to have the rotor rebalanced.

Faulty alignment or damaged foundations may cause vibration. It may be possible that incrustations on the turbine rotor may cause unbalance, and ultimately vibration.

Any damage to the turbine rotor blading (and balance weights) will, understandably, cause unbalancing of the rotor. All possible causes of turbine vibration should be investigated before an attempt is made to balance the rotor.

### Detecting Leaking Nozzle Control Valves

If not detected in time, leaking nozzle control valves for the main turbine will affect the operation of the propulsion plant. When the throttle valve is closed the main shaft will continue to rotate slowly in the forward direction, without any relative motion between the ship and the water. This abnormal rotation of the shaft can be stopped only by the use of the astern throttle valve or by closing the guarding valve.

In case of abnormal rotation of the shaft, or if there is any reason to believe that there is a leakage of steam at the high-pressure turbine nozzle control valves when the throttle valve is closed tight, a visual check should be made.

The test for leaking nozzle control valves can best be conducted when the ship is at anchor and the main condensing equipment is shut down. The guarding valve and throttle valves are closed in a normal manner. All steam and drain valves to the turbines are closed. The lagging pad and the inspection cover plate in the exhaust casing of the high-pressure turbine are removed; next the guarding valve, or its bypass, is slowly opened. A visual check of any steam leakage can then be made. There should not be any steam emitted from the opening in the turbine casing. If there is leakage, the amount of steam emitted will indicate the condition of the nozzle control valves. When there is steam leakage, all valves and lines should be rechecked to make certain that the steam is coming through the nozzle valves and not from another source. Precautions should be taken to ensure that the main throttle valve remains closed until the inspection plate has been replaced.

It is a good policy to make a visual check for leaking nozzle control valves each quarter.

## MAINTENANCE OF TURBINES

The maintenance of turbine installations is as important as their proper operation. If proper maintenance procedures are followed, abnormal conditions may be prevented.

The interior of the turbines is inspected quarterly, or more frequently (if necessary) by means of inspection openings. If time permits, all turbines are inspected after each long run or after considerable cruising. During this inspection, the effectiveness of the procedures in keeping the turbine dry and free from corrosion should be noted.

The following inspections and routine checks should be carried out at anchor, and appropriate entries must be made in the log:

| When | Where | Why |
|---|---|---|
| Daily | Jack turbines 1¼ turns | To prevent freezing of bearings. |
| Daily | Circulate lubricating oil in system | To prevent accumulation of water and sediment in pockets and to form oil film while jacking. |
| Daily | Run air ejector ½ hour, longer if necessary. | To dry out turbines. |
| Daily | Operate lubricating oil separator | To prevent water from being mixed with oil, when sent to bearings. |
| Weekly | Valves, and joints of steam, exhaust, and drain lines. | For tightness. |
| Weekly | Operate and lubricate throttle control gear. | To prevent sticking. |
| Weekly | Operate and lubricate, if possible, all valves not used. | To prevent parts from freezing. |
| Quarterly | Inspect exhaust trunk and last few stages of low-pressure turbine through manhole plate. | To detect corrosion or other defects. |
| Quarterly | Sound with hammer, holding down bolts, ties, and shocks of turbines. | To detect signs of loosening turbine fastening. |
| Quarterly | Remove turbine inspection plates | To determine existence of loose blades or shrouding, and to look for corrosion. |
| Quarterly | Shoes of thrust bearing for clearance and conditions of bearing surface. | To ensure proper position of the rotor. |
| Quarterly | Blow out thrust bearing with air after examination. | To prevent foreign matter remaining. |
| Quarterly | Main bearings for clearance | To ensure correct clearances. |
| Quarterly | Calibrate gages | To ensure correct readings. |
| Quarterly | Exhaust trunk | For tightness, evidence of corrosion, and loose bolts. |
| Quarterly | Test and set steam relief and sentinel valves. | To ensure proper protection against excessive pressures. |
| Quarterly | Check location, tightness, and condition of rotor balance weights through inspection openings. | To detect corrosion, erosion, or other defects. |
| Semiannually | Main bearings for clearance, condition of journal, and bearing surface. | To ensure correct clearances and good condition of bearings. |
| Semiannually | Gland packing, for wear (where examination can be made without lifting turbine casing). | To ensure efficient seal being maintained. |

## TAKING TURBINE BEARING READINGS

The oil clearances of bearings of all types, whether journal, thrust, or steady bearings, should be checked at regular intervals and the readings permanently recorded on the Bearing Record Card of the Material History.

1. QUARTERLY

   a. Take depth micrometer readings of all turbine journal bearings. When repairs are made, both depth gage and bridge gage readings should be taken and recorded.

   b. Take thrust bearing clearances on all turbine thrust bearings.

   c. Measure propeller thrust bearing clearance.

2. SEMIANNUALLY

   a. Take bridge gage readings of all turbine journal bearings. Depth gage micrometer readings should not be substituted for these bridge gage readings. Lead readings should be taken on the auxiliary turbines.

   b. Inspect the condition and the clearances of thrust shoes on thrust bearings. Inspect thrust collars, nuts, and locking devices.

3. ANNUALLY

   a. Examine the spring bearings for the main shaft and take clearances.

Instructions concerning what bearing readings should be taken, and how frequently these clearance checks should be made, are established by BuShips. In order that ship's personnel may thoroughly understand the applicable instructions, the type commander will usually amplify these instructions.

### Know Location of Rotor at all Times

Impulse main turbine installations are used on ships in the Navy with and without cruising turbines. All of the stages are the impulse type; that is, the type in which pressure drop takes place in the stationary nozzles. The steam is directed onto the curved surfaces of the moving buckets.

In impulse staging the radial clearances are large and have no effect on the efficiency. The axial clearances also, within the limits permitted by the design of the turbine, will have almost no appreciable effect on the efficiency, because the same pressure exists on both sides of the moving blades, thereby producing no tendency for the steam to bypass the blades. In impulse staging, axial clearances are kept small for the purpose of reducing the length of the rotor and casing.

In shaft and diaphragm packings the clearances are small, and will be altered if the position of the rotor changes (from wear either of the journal or of the thrust bearings). This change results in loss of efficiency of the turbine because of steam leakage by the glands, and repairs will eventually be necessary.

The most important reason for maintaining a turbine rotor in its proper position is to prevent damage to the turbine. Should the rotor touch the casing at any time, because of failure of the thrust or journal bearings while the turbine is in operation, damage will result and it will be necessary to lift the turbine casing for repairs. The turbine parts that are subject to damage, due to the close clearances, are the rotor blading, nozzle diaphragm blading, diaphragm packing rings, shaft packing rings, and oil deflector or seal rings.

### Bridge Gage Readings

Bridge gages are supplied with each turbine installation to detect any changes in the vertical and horizontal position (when cold) of the turbine rotors. Changes can result from worn bearings.

The gage is carefully placed over the journal so that the hardened steel resting points of the gage rest on the cleaned housing surface, and the dowels of the gage rest in the holes in the horizontal joint at the centerline of the bearing, as shown in figure 2–2. With feelers, measure the clearance between the journal and the top and side reference surfaces

*of* the bridge gage. The original clearance is stamped on the bridge gage, as is the name of the bearing on which the gage is to be used.

The difference between the reading stamped in the gage and the reading obtained with the feelers gives the amount that the shaft is above or below the proper position. This distance should agree within a few thousandths of the figure stamped on the gage. Data on allowable tolerances can be found in the manufacturer's instruction book or in chapter 40 of BuShips *Manual*.

The thickness of the oil film between the journal and its bearings will affect the reading. Bridge-gage readings, therefore, should be taken after the oil has been shut off for 24 hours. If it is impracticable to wait 24 hours after shutting off the oil supply, the interval between shutting off the oil and taking the readings should be made as long as possible.

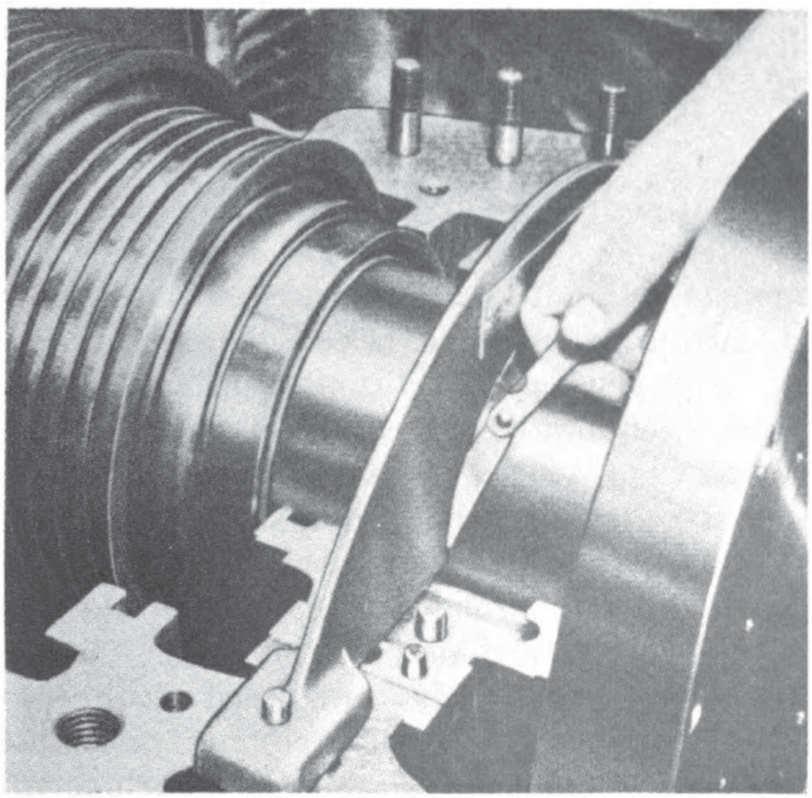


**Figure 2–2.—Taking a horizontal measurement with a bridge gage.**

Before a bridge gage is used, it should be examined to see that it has not been damaged in any way. Most ships are provided with gage pins to check for possible distortion of bridge gages.

### Depth Gage Readings

The bearing wear micrometer depth gage shown in figure 2–3 is used to determine the amount of bearing wear. The depth gage spindle is inserted into the depth gage well until the bridge of the gage rests evenly on the reference boss; the knurled handle of the micrometer is then turned until the spindle touches the journal. The reading is taken and compared with previous readings. The original reading for each bearing is stamped on the reference boss. Depth gage readings should not be taken while the turbine is in operation.

### Thrust Bearing Readings

There are a number of types of axial clearance indicators that can be used for various turbine installations. For example, a clearance indicator is used to indicate the axial position of the rotor without dismantling the turbine.

If an axial position indicator shows an abnormal indication, the clearance between the rotor and casing should be investigated. In addition, the thrust bearing should be inspected. A turbine should not be considered ready for operation until any abnormal condition resulting in an unusual reading has been located and corrected.

Checking Clearance of a Thrust Bearing. The total oil clearance of a thrust bearing can be obtained by measuring the end play of the rotor. Main turbines have the Kingsbury type thrust bearing, which must be completely assembled when measuring the end play of the rotor. Oil clearance of the thrust bearing must be maintained within the design clearances given by the manufacturer's instruction book and plans. Usually this oil clearance for a turbine thrust is between 0.008 and 0.015 inch.

The methods of measuring the end play of rotors for various types of turbines may differ in detail, but they employ the same basic principle. The rotor shaft is moved as far as it will go in one direction and then in the opposite direction. The length of travel between the two end positions

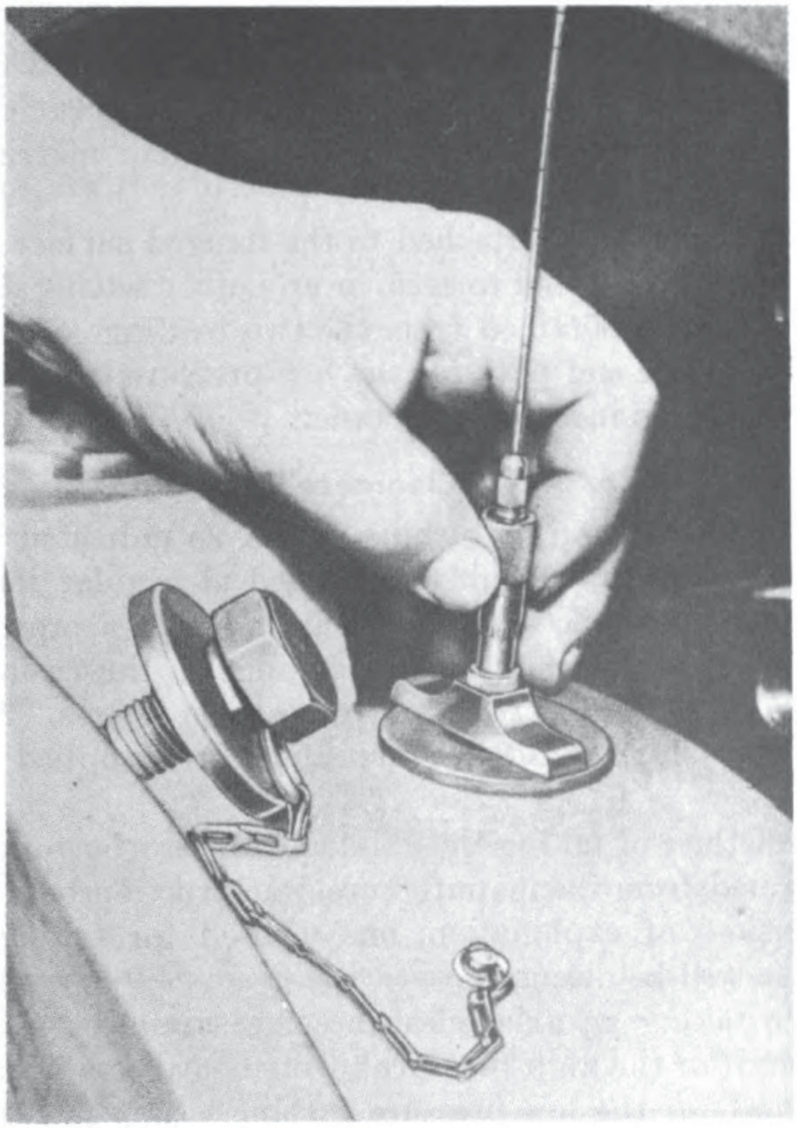


**Figure 2–3.—Taking readings with a depth gage.**

is measured by a precision measuring instrument, such as a dial indicator.

MOVING ROTOR TO CHECK END PLAY. The manufacturer's instruction book for a particular turbine installation should

be studied to obtain detailed directions for moving a rotor and shaft. One method of moving rotors is given below as an example.

In order to move the rotor shaft of the high-pressure turbine, remove the upper half of the coupling guard. To move the shaft forward, apply a bar between the after face of the coupling flange and the face of the adjacent cover. To move the shaft aft, a bar is applied between the forward face of the shaft coupling flange and the face of the bearing cap. In each case a wood block is used to prevent marring the metal surfaces.

The dial indicator attached to the flanged surface of the bearing cap is adjusted to zero, or any other setting desired. The end play is obtained from the two readings of the dial indicator. The end play for the low-pressure turbine rotor can be measured in a similar manner.

### Rotor Axial Clearance Readings

The axial location of turbine rotors, as indicated by the position indicators, should be checked at regular intervals by measuring the actual rotor clearance with a taper gage. On many propulsion turbines, openings in the casings are provided for the insertion of these taper gages. Special taper gages for taking these readings are supplied to the ship.

The method of taking the axial clearances of a rotor must be obtained from the manufacturer's instruction book. For the purpose of explanation, one method for taking these readings will be discussed.

When taking an axial clearance measurement, move the rotor shaft of the high-pressure turbine hard forward. The rotor shaft of the low-pressure turbine is moved hard aft. These positions will take up the slack between the thrust plate and the inner casing of the thrust bearing, duplicating the method used in obtaining the original readings.

A minimum clearance reading will be obtained for the high-pressure turbine, as indicated in figure 2–4. For the low-pressure turbine, a minimum clearance reading will be

obtained at the after-end astern element and a maximum reading will be obtained at the forward-end astern element. The clearance reading is taken by placing the taper gage between the face of the stationary bucket nozzle and the entrance edge of the first row bucket shrouding for both astern elements. In order to take these readings, two of the inspection cover plates have to be removed from the low-pressure turbine casing. The readings for the axial clearance of the rotor are taken at the same time that the clearance readings for the thrust bearing are taken.

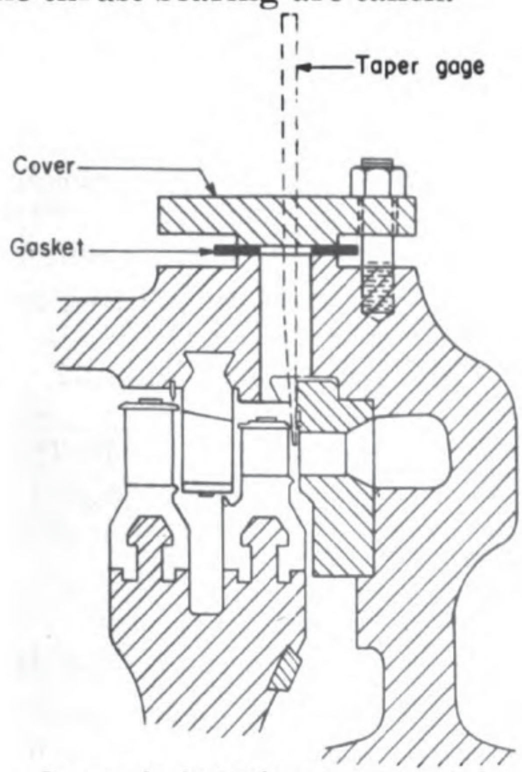



**Figure 2–4.—One method of taking rotor axial clearance readings.**

Turbine clearance readings are generally taken each quarter, to ascertain the actual position of the rotor and detect any abnormal wear of the bearings. If abnormal conditions are found, they should be investigated and corrections made before the turbine is placed back into operation. All clearance readings should be carefully checked against previous readings and recorded for future reference.

During a routine 5-year inspection, or whenever the turbine is opened for repairs, the repair activity normally will

take a detailed set of turbine clearance readings. These readings are recorded on a special form or drawing, and a copy is mailed to the ship. Figure 2–5 shows a method of taking taper gage measurements for checking the position of a high-pressure turbine rotor.

## REPAIR OF TURBINES

When a bearing is opened, it should be carefully inspected for ridges, scores, and amount of wear. It should be noted whether or not the babbitt lining has remained anchored to the shell. If the bearing is only slightly wiped, it can probably be scraped to a good bearing surface and restored to service. In this case the clearance reading of the reconditioned bearing should be fairly close to its original value. When a bearing surface is found to be scored, uneven, considerably worn, badly wiped, burned out, or if the lining is loose, the bearing should be rebabbitted or replaced.

### Journal Bearing Repairs

The journal should be carefully inspected. It should be smooth and even, and free from defects. To remove any rust, ridges, and sharp edges of scores, the journal should be lapped with a fine, small oilstone, or with an oilstone powder. This work, as well as scraping bearings, should be carefully performed by an experienced Machinist's Mate.

FITTING OF BEARINGS. A bearing should have sufficient percent bearing area or fit in order to withstand maximum designed load. If the bearing area is reduced by any considerable amount, more heat than the metal can withstand will be generated in the bearing, with the result that extreme measures will have to be taken to keep the bearing cool and prevent it from wiping.

Bearings are usually finish-bored to a diameter equal to that of the journal plus the desired oil clearance, and little or no fitting should be necessary. Where hand fitting is required, a mandrel should be used; the mandrel should have a diameter equal to that of the journal plus the desired oil

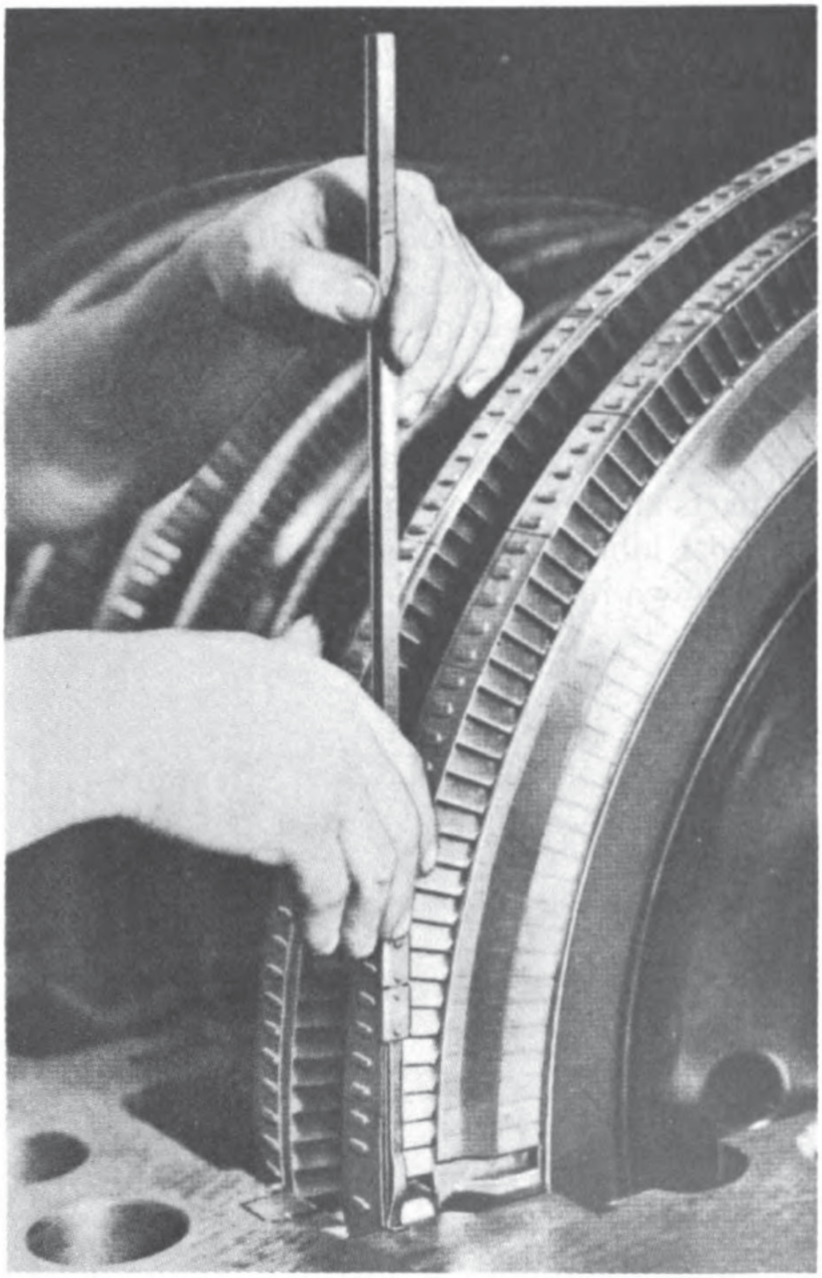


**Figure 2–5.—The position of a rotor being checked by a repair activity.**

clearance. The first step in hand fitting is to coat the mandrel with a compound such as prussian blue. One half of the bearing is placed on the mandrel and turned slightly, with a light pressure, to cause the coloring on the mandrel to adhere to the high spots on the bearing. These high spots should be removed with a scraper, and the fitting operation should be repeated until the coloring matter is uniformly

distributed over the bearing surface, indicating that all of the bearing surface is in contact with the mandrel. When no mandrel is used, contact with the journal should be limited to a small area (about 30°), in the bottom of the bearing.

In scraping a bearing, care must be taken to see that the lining is kept concentric with the shell.

REPLACEMENT OF JOURNAL BEARINGS. The detailed procedure for replacing bearings will vary somewhat for the different types and sizes of turbine. Where the upper and lower half of a bearing may be accidentally interchanged, or the axial position reversed, care should be taken to see that the parts are properly marked and replaced in order to obtain proper lubrication of the bearing. A typical turbine bearing is shown in figure 2–6.

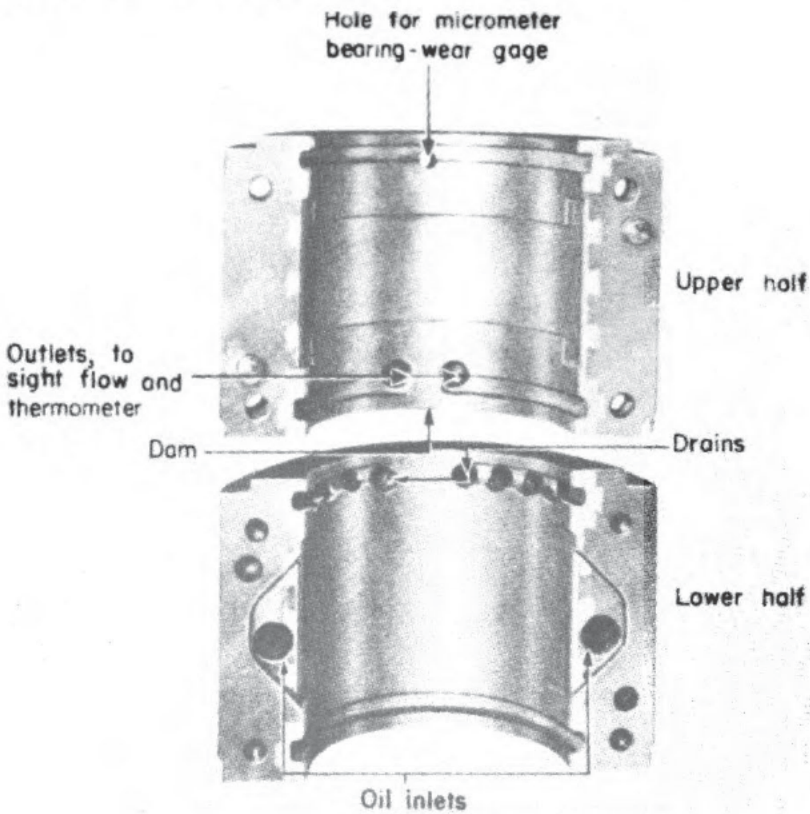



Figure 2–6.—Typical turbine journal bearing.

Before a spare bearing is installed it should be carefully cleaned and inspected. The two bearing halves should be bolted or clamped together and the vertical and horizontal

measurements of the bearing bore should be taken with an inside micrometer. Check to see that these values are within the manufacturer's dimensions. Just before installation the journal and bearing should be well lubricated.

As an example, in most turbine installations, after the upper half of the bearing has been removed, a special jack is used to remove the lower half of the bearing. The jack is put in place, as shown in figure 2–7, and the weight of the rotor removed from the lower bearing. There should be

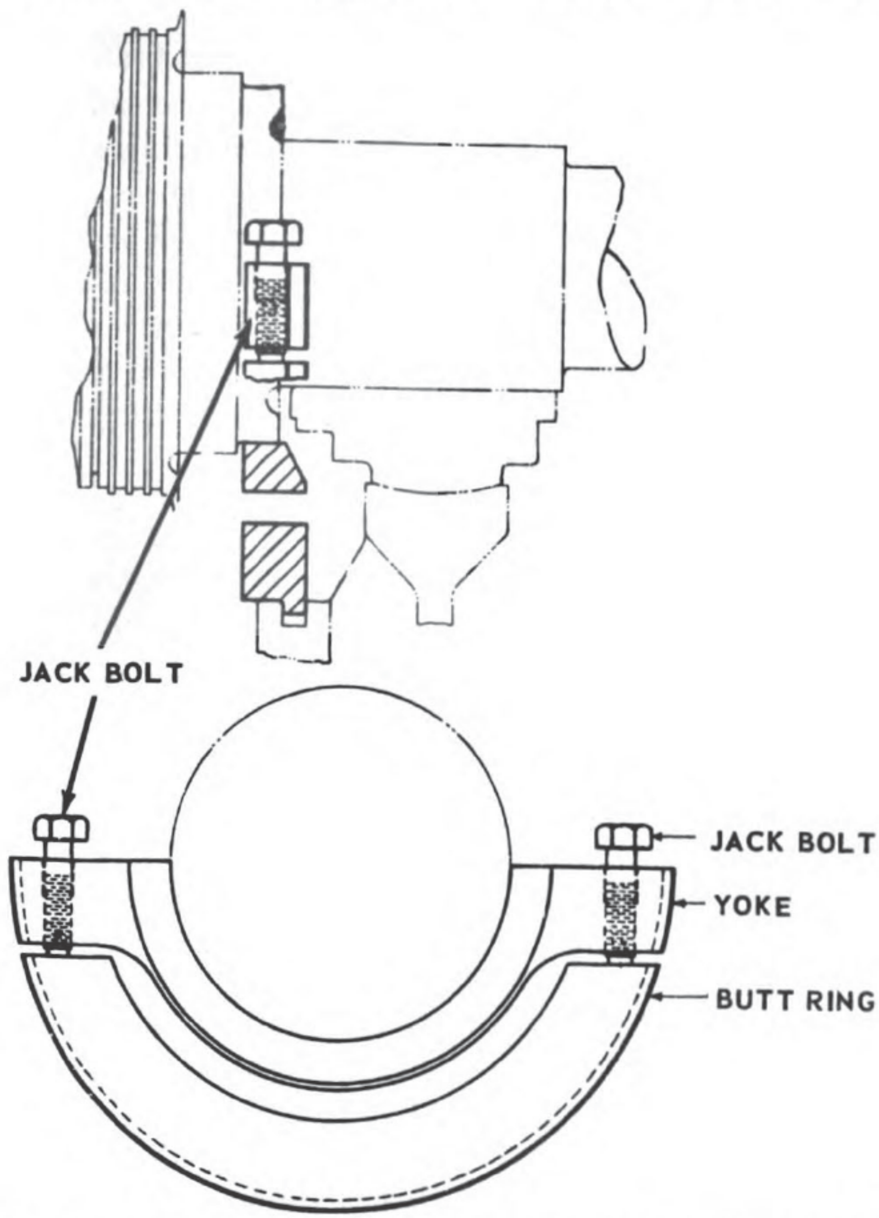



Figure 2–7.—Removing a lower half of a bearing with the aid of a special jack.

sufficient clearance so that the bottom half of the bearing can easily be rolled out and a spare bearing installed. When the lower half of the bearing is in place, the jack is removed.

With the rotor at rest on the lower half of the new bearing, bridge gage measurements should be taken and recorded. Depth gage readings should be taken and recorded after the bearing has been completely assembled.

The appropriate precautions should be taken to see that both the oil and the lubricating oil system are free from any impurities and foreign matter.

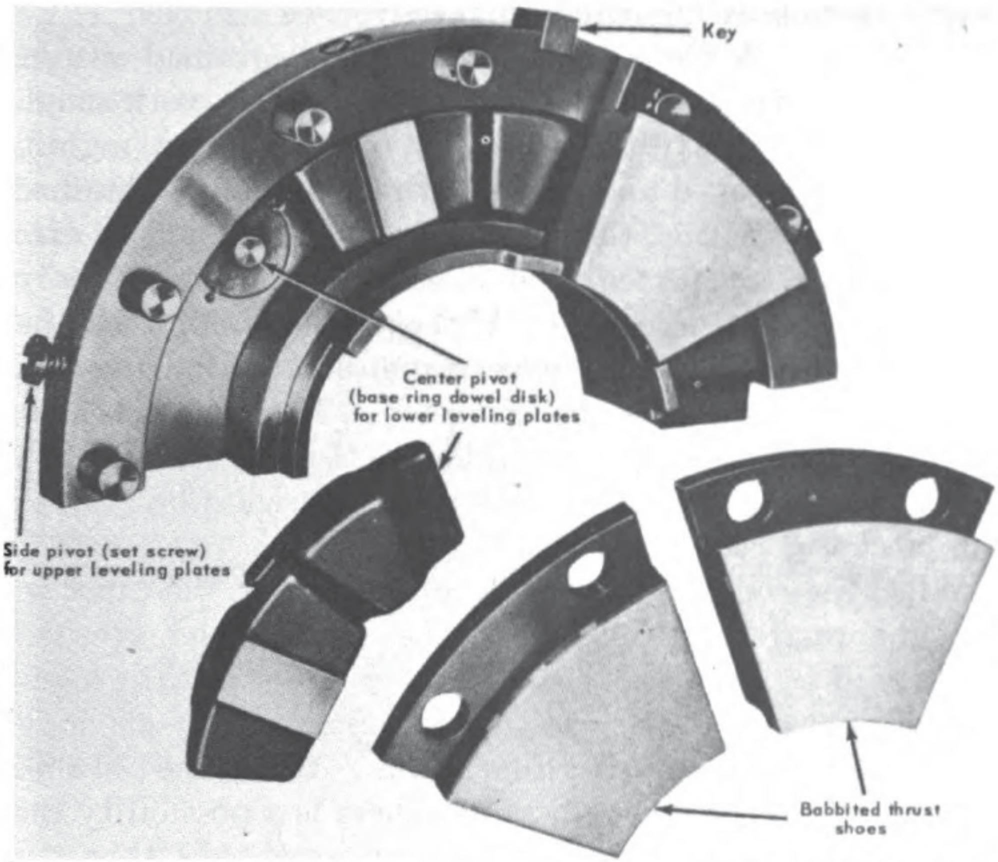
When a defective or burned-out bearing has been replaced by a spare, the old bearing should be rebabbitted without undue delay. If necessary, a new spare bearing should be ordered to maintain the required allowance of repair parts. The normal procedure is to have a repair ship or shipyard rebabbitt and machine out the bearing. The appropriate blueprints, or the manufacturer's instruction book, should be furnished the repair activity (except naval shipyards), because the detailed information will be necessary for rebabbitting and machining the bearing.

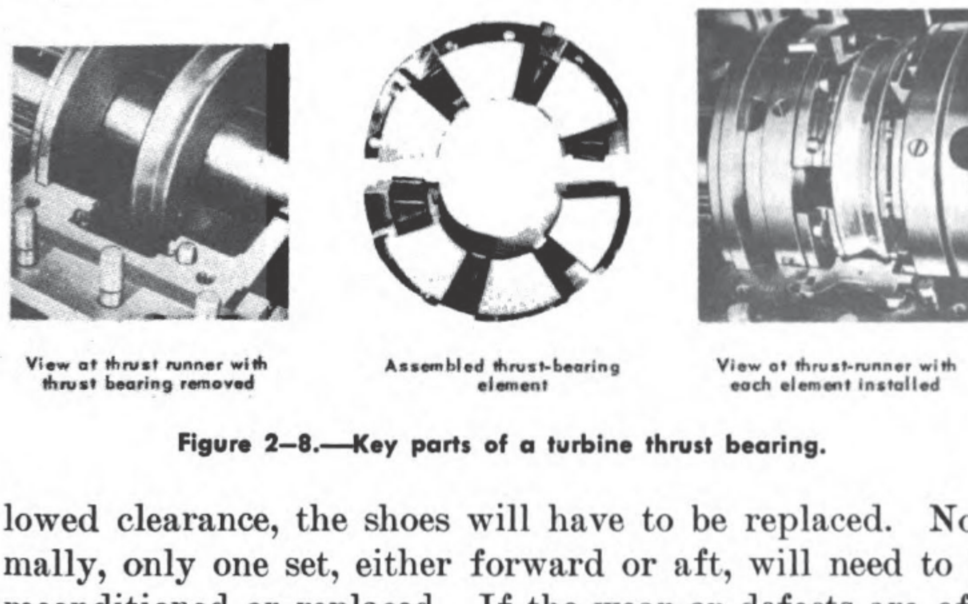
### Thrust Bearing Repairs

Should trouble occur in the thrust bearing, the turbine should not be operated until the thrust bearing can be opened for inspection and necessary repairs made. In order to know whether the bearing requires repair, you must be familiar with construction details and component parts. Study the views of the Kingsbury type thrust bearing in figure 2–8.

The thrust bearing shoes and base rings can be removed radially for inspection or replacement without disturbing the rotor shaft. The base rings are removed in halves. The shoes are attached to the base rings. The lower half of the oil-control ring can be rotated and lifted out when the thrust bearing housing is being cleaned.

The amount of clearance or wear in the thrust bearing should be measured before the thrust bearing is disassembled. If the readings are abnormal, or beyond the maximum al-



View of thrust runner with thrust bearing removed

Assembled thrust-bearing element

View of thrust-runner with each element installed

**Figure 2–8.—Key parts of a turbine thrust bearing.**

lowed clearance, the shoes will have to be replaced. Normally, only one set, either forward or aft, will need to be reconditioned or replaced. If the wear or defects are of a minor nature, the shoes and other parts can be reconditioned and reinstalled.

A careful inspection should be made of all parts, and any bruises on the shoe faces should be removed with a scraper.

Slight rusting of the collar surfaces can be removed with a fine oilstone. A file, a scraper, or a coarse-grained oilstone should never be used on the thrust collar. The work should be performed slowly and carefully to ensure that nothing has been overlooked and that good results will be obtained.

Before installation, the spare thrust shoes should be carefully cleaned, inspected, and oiled. Do not use force in assembling a thrust bearing. If the parts do not go together easily an inspection should be made, because something is out of place and must be corrected. The thrust bearing housing should be bolted down before the end play is measured. If proper readings are obtained for end play, the job can be considered completed.

When the end play is too much or too little, the cause for the abnormal condition should be located and rectified. There will be no trouble encountered in the use of the manufacturer's spare thrust shoes, as they are accurately machined and surfaced to the proper dimensions. Where the old shoes have been scraped and reinstalled, there is a possibility that too much bearing metal has been removed. In this case, an end play beyond the maximum clearance will be obtained. This situation can be prevented by taking an end play reading before disassembling the defective thrust bearing. If the shoes require rebabbitting and machining, refer to the blueprints for detailed measurements.

When the end play is too much, however, the best procedure is to install a spare set of thrust shoes.

Damaged thrust bearing shoes which cannot be reconditioned by the ship's force are sent to a repair activity, to be rebabbitted and machined. The bearing surfaces are scraped to an accurate surface plate and the radial edges rounded slightly. The work is performed in accordance with the directions and dimensions given by the manufacturer's blueprints or instruction book. When the thrust bearing shoes have been returned to the ship, it is a good idea to inspect and measure them. Spare thrust shoes should be carefully cleaned, preserved, and placed in the proper stowage place.

Scored Thrust Bearing Collar. If a thrust bearing

collar (or runner) is found to be badly scored or if deep rust pits are present, the collar should be removed for repairs. On most turbines the thrust collar can be removed without lifting the casing and without disturbing the lower half of the forward journal bearing.

On some installations, the thrust collar (runner) is keyed to the shaft and held in place with a nut and a special type of lock washer. From a study of figure 2–9, you can see that the lower half of the inner casing of the thrust bearing will

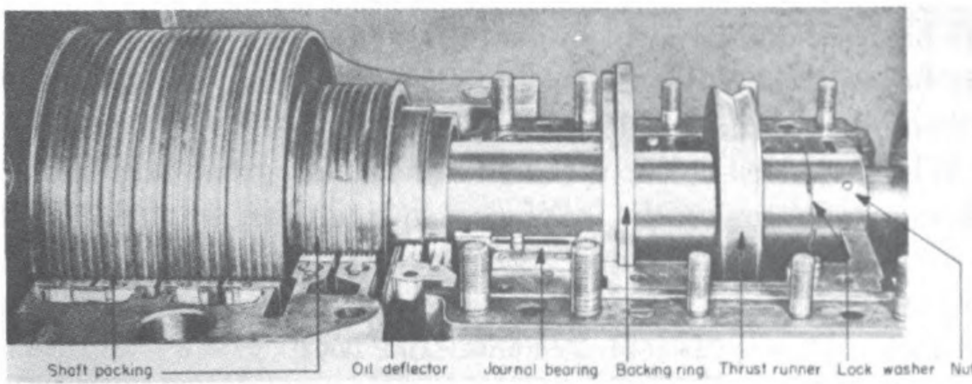



**Figure 2–9.—A typical view of the forward end of a high-pressure turbine.**

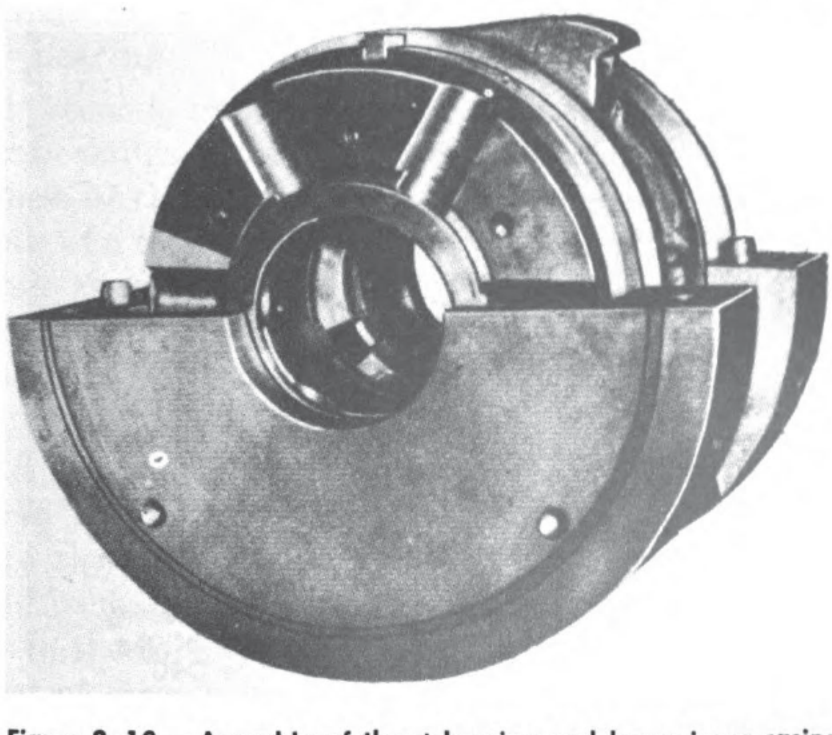


**Figure 2–10.—Assembly of thrust bearing and lower inner casing.**

have to be removed before the thrust collar can be removed over the end of the shaft. The lower inner casing, together with the assembled thrust bearing, is shown in figure 2–10.

The lower inner casing is removed from the outer thrust bearing casing (or housing) by rotating it 180° and lifting it from the turbine. The lower half of a journal bearing is removed similarly, except that a chain fall may be required.

The parts, as shown in figure 2–11, are removed with the use of special tools which are provided. The thrust collar can be drawn off by applying a puller to the tapped holes near the bore of the collar. In most cases, a spare thrust collar is provided and should be installed.

When a thrust collar is to be remachined, great care should be taken to make the surfaces square and smooth. The

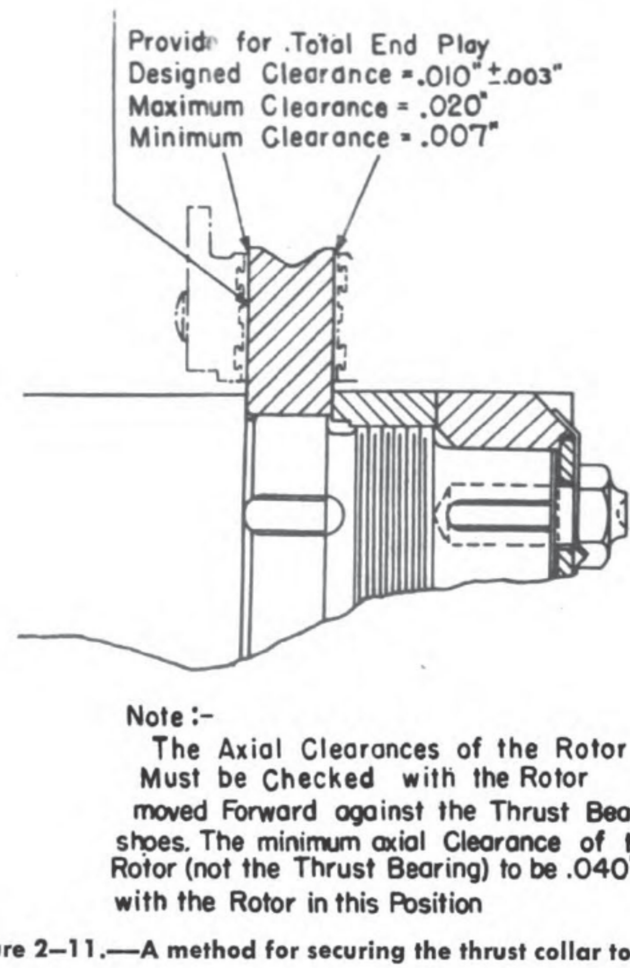



Figure 2–11.—A method for securing the thrust collar to the shaft.

thickness should be kept exactly uniform all around, and the marks left by final machining or grinding should be removed by lapping. Normally, the thrust collar should be machined by a repair activity.

ADJUSTING THE POSITION OF THE TURBINE ROTOR. The end play of the turbine rotor is maintained by the thrust bearing. This end play is determined by the thickness of the filler piece, located between the forward base ring and the inner casing of the thrust bearing.

The axial position of the turbine rotor is maintained by the location of the inner casing of the thrust bearing. The inner casing is positioned by two shims located between the inner casing and the outer casing (or housing) of the thrust bearing.

The turbine rotor is set in its axial position at the factory, and the two shims are machined to the required thickness and installed. In most cases they are split and fastened to the inner casing of the thrust bearing. The axial position of the rotor is again checked when the turbine is installed. Under normal circumstances, there should be no need to alter or change the established position of the inner casing of the thrust bearing.

If it becomes necessary to give greater oil clearance to the thrust bearings and if no repair facilities are available, the thickness of the filler piece may be changed. This would be a repair of a temporary nature and permanent repairs should be made as soon as practicable. When spare thrust bearing shoes (in good condition) are available or when thrust shoes can be rebabbitted, there should be no need for changing the thickness of the filler piece.

If it becomes necessary to use reconditioned thrust shoes, the end play or oil clearance should be carefully checked. Where the maximum oil clearance is exceeded, corrections should be made. The best method is to put the worn set of shoes in the forward position. Care should be taken, when one set of shoes is badly worn, not to interchange shoes between the forward and after sets. The worn shoes should

be carefully scraped and put into as good a condition as possible.

When the oil clearance has been taken, the thickness of the shim to be added should be computed. Take, for example, a thrust bearing that has the following clearances: designed clearance 0.010 inch; maximum clearance 0.020 inch; minimum clearance 0.007 inch. If a reading of 0.025 inch was obtained, a shim of 0.015 inch should be installed. A circular shim should be made from a sheet of shim material. More than one shim may be used to obtain the proper thickness.

The advantage of placing the shim, with the filler piece and the under-sized thrust shoes, in the forward position is that the turbine rotor will be maintained in its original position. Also, it is by far the easiest and quickest method for making an adjustment in the oil clearance of the thrust bearing.

### Renewal of Shaft Packings

Under normal conditions, if it becomes necessary to repair or replace the main turbine shaft packing, the job will usually be accomplished by a naval shipyard or by another repair activity.

When necessary, the outer rings of packing for most high-pressure turbines can be replaced by the ship's force, since this can be accomplished by removing the upper half of the packing casing. The inner packing rings cannot be replaced aboard ship, as it would require lifting of the turbine casing. Some high-pressure main turbines in the Navy have only labyrinth packing. Other high-pressure turbines have labyrinth and carbon packing in the low-pressure end.

Where low-pressure main turbines use only labyrinth packing, both the inner and outer packing are accessible when the upper half of the packing housing is removed. On low-pressure main turbines where carbon packing is used, this packing can usually be replaced by the ship's force.

When it becomes necessary for the ship's force to replace the shaft packing, the detailed instructions in the manufacturer's instruction book should be followed for a particu-

lar installation. Spare packing rings are usually provided in the ship's allowance of repair parts. The segments of a given packing ring should not be interchanged or rearranged. The sequence of marking on the ends of the segments should be followed.

### Sealing of Turbine Flange Joints Aboard Ship

The horizontal and vertical joints of the high-pressure and the horizontal joints of the low-pressure main turbines are grooved for filling with sealing compound when the turbines are installed or when major repairs have been made by a shipyard. These grooves are filled only with an approved sealing compound when the flanged joint shows signs of steam leakage in service.

Two commonly used compounds are Furmanite and copaltite. The use of Furmanite is restricted to temperatures not exceeding 425° F. Copaltite is satisfactory for temperatures up to 850° F.

When it is necessary to fill the groove, the location of all the tapped holes for use in filling the groove should be checked by referring to a manufacturer's drawing. All the turbine flange bolts should be tight. The pressure pumping grooves should be gunned when the turbine is cold, as the sealing compound solidifies when subjected to heat and will not readily flow the full length of the groove.

A pressure gun with two nozzles and a supply of sealing compound is furnished the ship. Remove one end plug and the adjacent plug; start at one end and inject the sealing compound with the pressure gun until it overflows through the adjacent hole. Plug the first hole and attach the gun to the adjacent hole. Remove the threaded plug from the next adjacent hole and fill the next section of the groove. Continue in the same manner until the entire groove has been filled. The operation should be performed as quickly as practicable, so that it will be completed before the sealing compound hardens. When the gun is in the next to the last hole and the sealing compound is flowing from the end

hole, plug the end hole and put pressure (with the gun) on the whole groove. Then remove the gun and plug the last hole.

### Nozzle Control Valve Repairs

The nozzle control valves for the main high-pressure turbine normally will operate for a long period of time without any maintenance or repairs; however, trouble may occur from time to time. The MM1 or C should be familiar

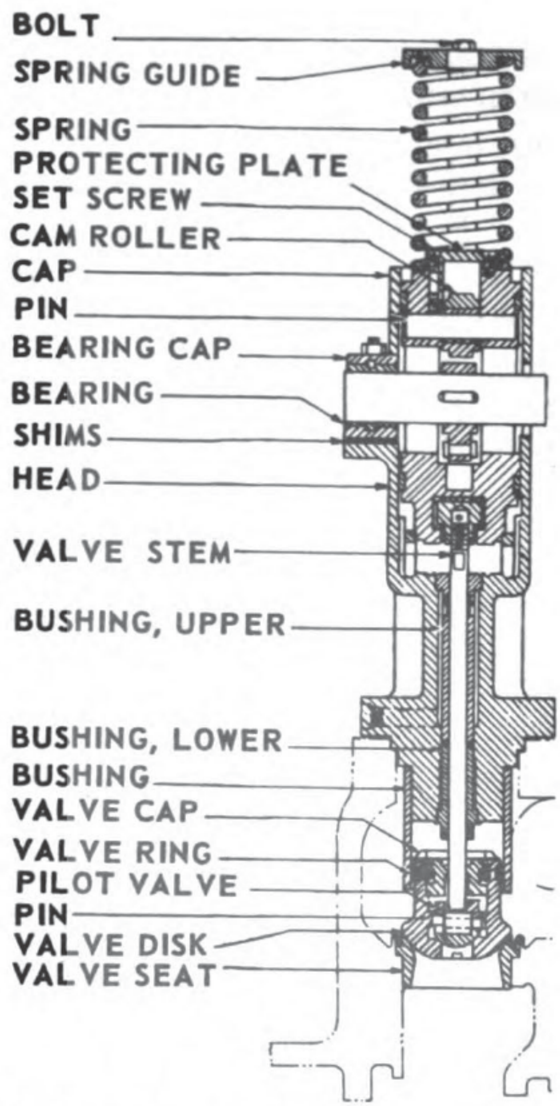



Figure 2–12.—A turbine nozzle control valve.

with the detailed construction of the nozzle control valves installed on his ship and the types of troubles that may occur.

Most nozzle control valves to the main turbine are quite similar in operating principle and construction. Figure 2–12 shows the construction details of a common type of nozzle valve, which is located in the centerline of the turbine steam chest. There will be a slight difference in construction of the nozzle valves located on each side of the centerline. Figure 2–13 shows enlarged sections of the nozzle valve shown in figure 2–12.

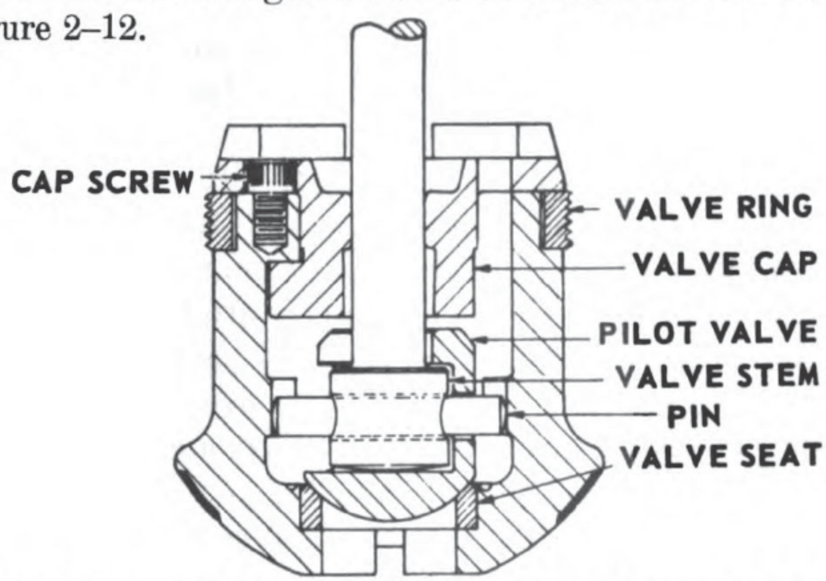



Figure 2–13.—Enlarged section of a turbine nozzle control valve.

The nozzle control valves are subjected to high steam pressures and temperatures, and after a long period of time they become very difficult to remove. The valves are located close to each other, and this adds to the difficulty of their removal. The removal of the nozzle control valves from the main high-pressure turbine should not be attempted by the ship's force if the services of a repair activity are available. Repairs to the nozzle control valves of the main high-pressure turbine are generally made by a naval shipyard.

One of the troubles that may occur to turbine nozzle control valves is the leakage of steam between the valve seat and disk. This type of defect is also common to high-pressure steam valves but the nozzle control valves are more

difficult to repair, because they have seats and disks with spherical contours. The valve seats and disks are carefully lapped to make them seat tightly, even if slightly out of line. A repair activity will make up special cast-iron lapping blocks for lapping the seats and disks. One cast-iron lapping block, with the same designed contour as the disk, is used to lap the seat. Another lapping block, with a concave lapping surface to match the designed spherical curvature, is used to lap the valve disk. When the valve seat and disk surfaces have been refinished, the contact surface between the seat and disk are checked by the use of prussian blue. If the valve seats or disks are badly steam-cut or damaged, they should be replaced.

Foreign matter will interfere more with the operation of the pilot valves in the nozzle control valves than with the main valves. There is a possibility that the pilot valves may leak steam while the main valves are tight. The pilot valves should be inspected and repaired, as found necessary, when the turbine nozzle control valves are disassembled for repairs. The same procedures for repair and lapping apply to the pilot valve seats and to the disks.

Unsatisfactory operation of the turbine nozzle valves may result from the valve stem sticking inside its bushings. The designed clearance between the valve stem and the two bushings is very small, in order to prevent a large amount of steam from escaping. Foreign matter and a bent valve stem will prevent the steam from moving freely. If a nozzle valve sticks it will not close properly, and steam will enter the turbine when the throttle wheel is in closed position. A sticking nozzle valve of this type must be disassembled for repairs. If foreign matter is the cause of the trouble, the valve stem and its bushings may be cleaned and restored to service. In some cases it may be necessary to renew the valve stem and the upper and lower bushings. In order to accomplish repairs, the nozzle control valve will have to be removed from the turbine steam chest.

Troubles have occurred where there are steam leaks in the upper turbine casing, between the steam chest and the tur-

bine. Leaks of this type are caused by steam cutting a passageway between the nozzle valve seat and the upper half of the turbine casing. Such leaks are located by tests performed by a naval shipyard or other repair activity. The tests are made by blanking off the valve openings. The steam chests are partially filled with water, and compressed air is admitted to the interior of the turbines. If there are any leaks, they can be located by observing the air bubbles passing through the water. Repairs are made by removing the upper half of the high-pressure turbine casing and transferring it to the shipyard shops for welding and machining. When the nozzle control valves are reassembled, the proper adjustments are made for the length of the valve stems and the proper sequence of operation of the cams.

Routine shipboard tests will indicate whether or not there are any main high-pressure turbine nozzle control valve leaks. In case nozzle valve leaks are detected, there are no methods of locating the cause of the leak except by disassembling and inspecting the nozzle valves and steam chest. Repairs of this nature are normally considered beyond the capacity of the ship's force. (It is best that repairs of this nature be accomplished by a naval shipyard, as the trouble may be due to a leak in the high-pressure turbine upper casing or steam chest casting.)

## LIFTING MAIN TURBINES

Under normal conditions, the lifting of the ship's propulsion turbines, with the associated inspections and repairs, is usually done at naval shipyards. However, ships are provided with turbine lifting gear, special tools, and repair parts, so that emergency repairs can be accomplished by tenders, repair ships, or advanced bases.

Depending on the size and type of the turbine, it is recommended that the main turbine casings be lifted about every 5 years. The decision as to when casings should be lifted will be made by BuShips. This decision will be based upon the past performances of the particular type of turbine, data

furnished by the CO of the ship, and recommendations made by the forces afloat. In an emergency, turbine casings may be lifted before permission is granted, but a detailed report must be promptly submitted to BuShips.

### Regulations Regarding the Lifting of Turbines

To aid BuShips in making this decision, it is requested that 3 months prior to each regular naval shipyard overhaul (not limited or restricted availabilities) the CO submit a report, via the appropriate superiors in command, to BuShips, giving in detail the following data:

1. A record of the turbines, main and cruising, whose casings have not been lifted within 5 years preceding both the forthcoming and the next succeeding overhaul.

2. The specific date when the turbine casings were last lifted, the date when the rotor was last lifted, the date of the last inspection through the inspection plates and the exhaust trunk, and what parts of the turbine were sighted.

3. The original bridge-gage reading, the maximum deviation since the turbine was last opened, the present reading, and the reading when the turbine was last opened. State the original clearance between fixed and moving rows of blades as determined by micrometer gage, taper gage, or finger piece. Give the present reading and the departure, if any, from the original reading.

4. A statement as to whether or not the operation of the turbine has been and is satisfactory.

5. A statement as to whether or not the CO believes that the operation of the turbine will be satisfactory for the next 12 months.

6. A recommendation from the CO in regard to the lifting of the casing.

7. A statement as to whether or not the work is within the capacity of the ship's force.

No valve, fitting, plate, or attachment, the removal of which will give access to the interior of a turbine, should be removed except on specific authority of the engineer officer.

When any part of the turbine is open, great care must be exercised to prevent any foreign substances from entering the casing. The turbine inspection plates should not be left off overnight, nor for any considerable length of time unless the opening is well covered. Any person inspecting the interior of a turbine should make sure that all foreign substances, such as pencils, combs, and tools, are removed from the pockets of his clothing.

Before reassembly of a turbine after it has been opened, a very careful examination should be made of the rotor and the interior of the casing for any articles left behind (chisels, hammers, screw drivers, etc.). This examination should be made (1) before the rotor is lowered into place, and (2) before the casing is lowered and secured in place. These inspections should be made by a responsible officer of the ship and, in case the work is being done by a naval shipyard or tender, a responsible officer of the assisting activity should also inspect. A specific entry, together with names of inspecting officers, should be made in the engineering log.

After the turbine has been reassembled, oil should be circulated through the bearings, the rotor should be jacked slowly, and care should be taken to detect unusual sounds. Should any unusual noise be heard, steps should be taken to determine and remedy the trouble before the turbine is used.

### Lifting Casing and Rotor for Inspection and Repairs

Although shipyard personnel may supervise and are usually responsible for lifting casings and rotors, the MM1 or C should have a good understanding of the procedures and work involved. As a ship's inspector, the MM1 or C should see that all work being performed by a repair activity is satisfactory to the ship.

Before a turbine casing is lifted, a certain amount of preliminary work has to be done. All the turbine lifting gear should be assembled, inspected, and inventoried a day or two before the work starts. Most ships have a blueprint that lists all turbine lifting gear placed on board ship. The manufacturer's instruction book and the ship's allowance

book can also be used for checking the turbine lifting gear. Ship's force should be ready to furnish this turbine lifting gear, which includes chain falls, special wire slings, shackles and other attachment clamps or pieces, casing guide pins, casing supports, rotor guide pieces, rotor support brackets, lifting bar or bracket, and other smaller items.

Before the casing can be lifted, the guards and the flexible coupling between the turbine and reduction gear must be disassembled and removed. In case a cruising turbine rotor is to be lifted, the crusing turbine reduction gear also must be disassembled, as the pinion is part of the turbine rotor shaft.

Sections of the main steam lines are disconnected from the turbine and removed. The crossover line from the high-pressure to the low-pressure turbine is disconnected and removed. Small lines may be removed from the turbine, if necessary. In some cases, overhead obstructions to lifting, such as steam lines and ventilation ducts, may have to be removed. If necessary, turbine heat insulation, such as blankets and pads, may be removed from the turbine. Some consideration should be given to the proper temporary stowage of the various piping and material in the engineroom. Care should be taken to keep passageways and working areas as free as practicable. Damage to piping and turbine insulation and lagging should be avoided as much as possible. Small items such as gage lines and fittings may have to be protected by temporary guards.

After the preliminary work has been completed, or in many cases while this work is in progress, the turbine casing horizontal joint bolts are removed. As a rule the vertical joint bolts on the high-pressure turbine are not removed except where repairs require the joint to be opened. Care must be taken to see that internal casing bolts are removed. The inspection opening covers carry caution plates calling attention to internal bolts. The bolts for the bearing upper housings are also removed. When disassembling main turbine casing bolts that were tightened by heat, it is important

that heat by a torch be applied to prevent galling of the threads. If there is a tendency for the joint to spring open at disassembly, it is good practice to lubricate the threads of the first few bolts that are loosened, and then retighten them lightly. These bolts can easily be removed last. After all the bolts have been removed, the casing joint can be broken loose by means of jack bolts.

When a ship is built, pad eyes are installed in the overhead of the engineroom for the purpose of attaching chain falls for lifting heavy machinery such as main turbine and reduction gear upper casings and rotors. The manufacturer's blueprints and instruction books will give detailed information on the arrangement, number, and capacity or size of chain falls, wire slings, and shackles to be used for lifting a particular turbine casing and rotor. The lifting arrangement will usually allow the four corners of the upper casing to be lifted equally and in a horizontal plane kept parallel to the lower flange joint. Four upper casing guide pins are

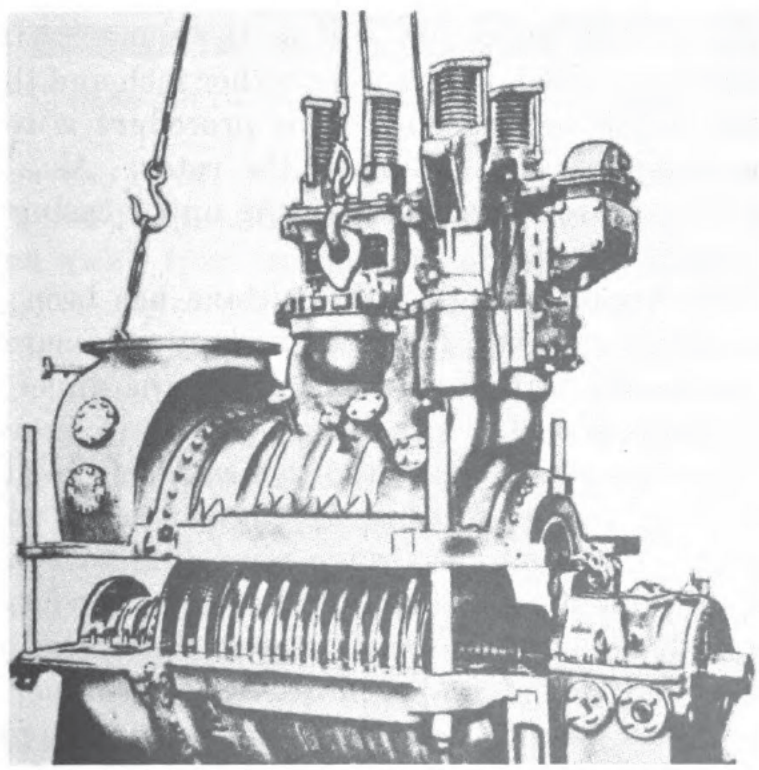


**Figure 2–14.—Lifting or lowering upper casing of a high-pressure turbine.**

installed. If there is a scale on the guide pin, this scale should face outboard where it can be readily seen. The location of the upper casing guide pins is shown in figure 2–14. These guide pins are used to prevent any damage to the turbine blading and packing rings when the upper casing is raised or lowered.

When lifting operations are ready to commence, men are assigned various jobs and stations. Under normal procedures, it will require about 10 or 12 men to raise or lower a main turbine casing. About 4 to 6 men operate the chain falls. Four men, one at each corner of the turbine casing, take measurement readings from the guide pins or (most commonly) by the use of a ruler or tape measure. One observer is usually stationed on each side of the turbine. One man supervises the whole operation. The casing is slowly "inched up" by chain falls, and continuous measurements are taken to ensure that the casing is level and not tilted. The usual procedure is to raise the casing one inch and stop. Then adjustments are made as necessary so that the height at each guide pin will be the same. After the casing has been leveled, it is raised another inch and the same checks and adjustments made. This procedure is repeated until the upper casing is clear of the rotor. As a safety measure, blocks are inserted under the upper casing flange as the casing is raised.

When the upper casing of the turbine has been raised, it can be either removed from the turbine or secured in a position above the turbine. In either case the upper casing of the turbine is placed in a position as shown in figure 2–15.

After the casing has been raised to a sufficient height, and not above the casing guide pins, the 4 upper casing supports are installed adjacent to the guide pins, as shown in figure 2–15. Applicable blueprints should be on hand when a turbine is lifted, to show the exact location for installing the various turbine supports and guide pieces. The upper casing support pieces are firmly bolted to the lower and upper turbine flanges. Figure 2–15 shows a turbine opened up for inspection.

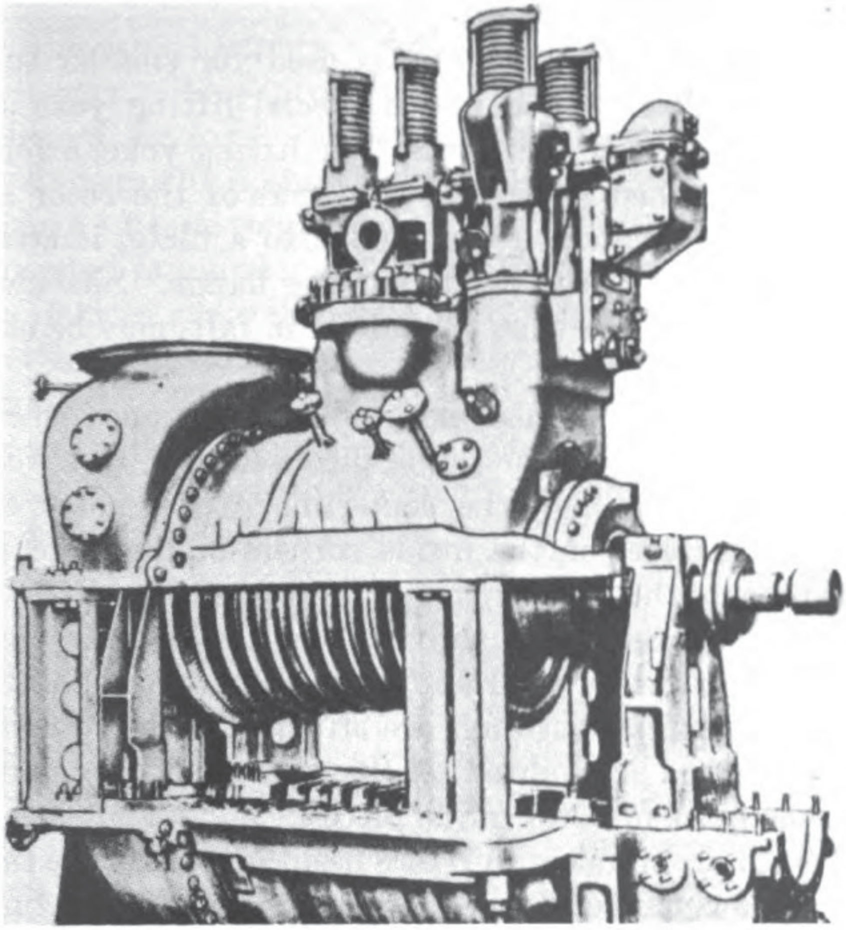


**Figure 2–15.—Upper casing and rotor on supports.**

In case the rotor, or upper casing, of a main turbine has to be raised for repairs or for removal, the upper casing is moved away from its position above the turbine. With the upper casing secured, as shown in figure 2–15, the rigging arrangement of chain falls and slings is changed and the casing is hoisted clear of the guide pins and supports. The casing is moved to a convenient adjacent location in the engineroom; in some cases the casing is removed from the ship. Where the upper casing is to be moved away from the turbine, the rotor will not be raised until the casing has been removed. (See fig. 2–15.)

A similar procedure is used for lifting the turbine rotor as was used in lifting the upper casing. Four rotor guide pieces are attached to the lower casing of the turbine, as shown in figure 2–16. There are different methods of attaching the wire slings (or chain falls) to the turbine rotor. One

method, shown in figure 2–16, is used for smaller turbine rotors. Another method uses a special lifting yoke and a lifting plate to raise the rotor. The lifting yoke, a form of clamp, is attached to the forward end of the rotor shaft. The lifting plate, a pad eye welded to a plate, is attached to the after face of the shaft coupling flange. Shackles are attached to lifting devices so that chain falls may be used in lifting the rotor.

The rotor guide pieces perform two functions: when the rotor is being raised, the guide pieces keep it in a vertical plane passing through the centerline of the rotor shaft; machined surfaces on the inside corners of the rotor guide pieces prevent the rotor from moving forward or aft. These machine surfaces bear with a small clearance against shoulders on the forward and after ends of the shaft. In many cases, special bushings are attached to the rotor shaft. These bushings are located on the sections of the shaft between the pairs of rotor guide pieces.

After all preliminary work has been completed, the turbine rotor is slowly lifted from the lower casing of the turbine. The rotor is lifted approximately one inch and measurements taken at each end to ensure that both ends have been

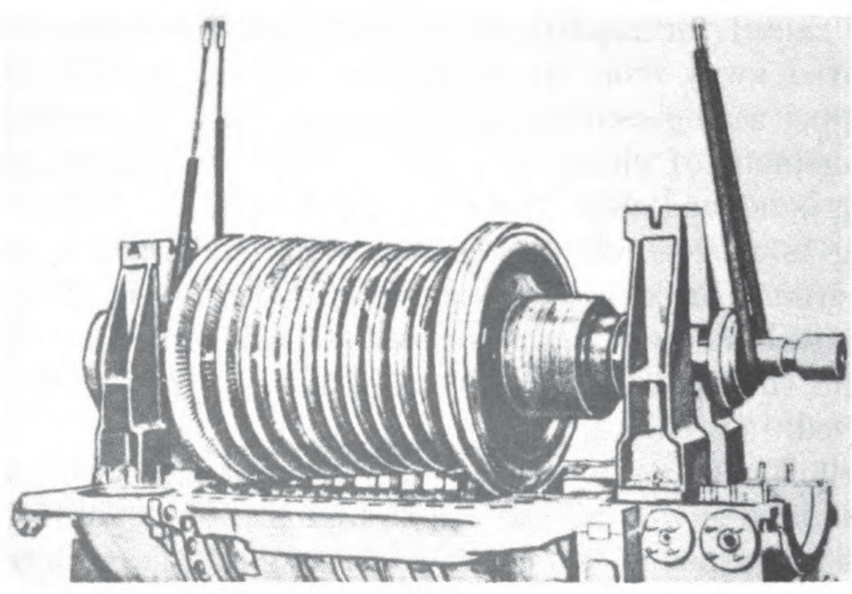


Figure 2–16.—Lifting high-pressure rotor.

raised the same distance. Adjustments in height are made as necessary. This procedure is repeated until the rotor has cleared the lower casing. A rotor that has been lifted clear of the casing is shown in figure 2–16.

When a turbine rotor is to be placed in its raised position, as indicated in figure 2–15, special securing devices are used. These devices are items such as rotor guide saddles, rotor supporting bars, rotor guide tie brackets, and rotor guide spacer bolts. These attachments are carefully secured in place so that the weight of the rotor can be properly supported. Similar procedures are used for lifting and securing the low-pressure turbine rotor.

### Sealing Flange Joints

Care must be taken in making a turbine casing joint. Joints should have accurately scraped parallel surfaces, or the edges of large flanges may be given a clearance outside the bolt holes as necessary (about 0.006 inch per inch of flange width outside the bolt holes) to ensure all-around contact on the inner edges. The flanges must be scraped absolutely clean and then polished with crocus cloth. The necessity for protecting the finish of the flanges during an inspection and repair period should not be overlooked. There are several approved materials used in making the joints, any one of which will give satisfaction if used under proper conditions.

As a jointing material, manganesite is favored by a large number of turbine repairmen; however, the principal objection offered to its use is that the joint once properly made is sometimes hard to break.

In preparing manganesite for use it is ground to a fine powder and placed in a metal container with a small quantity of boiled linseed oil. The mixture is then heated in a double boiler until the material is thoroughly dissolved in the oil and forms a smooth soft paste about the consistency of molasses.

Both the upper and lower flanges of the casing are completely covered with manganesite. This is done when the

upper casing has been lowered to a position about one foot above the lower casing flange. Manganesite is applied with a brush. The joint where the gland packing casing is secured to the turbine should be made up with the same care as that of the main turbine joint.

Graphite and boiled linseed oil are used in making turbine-casing joints. This mixture has about the same consistency as manganesite and is also applied with a brush. The same care must be taken with this material as with manganesite.

Flange joints may also be made up with usudurian when the temperature does not exceed 425° F. This material is used for low-pressure turbine joints. When usudurian or another approved type of unvulcanized sheet-rubber packing is used, it should be applied in strips not more than ½ inch wide and not more than $\frac{1}{32}$ inch thick, so that it will flow sufficiently to prevent appreciable separation of flange faces when the joint is finally set up, and will withstand the temperature conditions and permit reasonable ease in breaking joints in service. After the turbine is closed and the securing bolts set up, the turbine is thoroughly heated up and the casing bolts are again set up. Usudurian is especially effective when the faces of flanges are not in the very best condition. Usudurian dissolved in carbon tetrachloride may also be used as a joint compound.

When the temperature exceeds 425° F, the use of copaltite in both paste and liquid forms has been found satisfactory. The liquid form should be used unless the flanges are in poor condition. With the use of this compound, there must be absolutely no oil or grease on the faces to be made up. It is recommended that the faces be cleaned with nonleaded gasoline. Coat both surfaces lightly with the copaltite liquid by brushing. Permit the compound to become tacky before bringing the flanged joints together. Copaltite contains alcohol which must be given time to evaporate.

Copaltite is a thermosetting phenolic compound with 7 percent alcohol added as a retardent. Thermosetting compounds have the property of deteriorating or setting in storage. Copaltite, as manufactured, has a useful storage life

of about one year at a temperature of 65° F. Six months storage at 110° F will render it unusable. The material in cans has a slightly longer life; but once a container is opened the material deteriorates rapidly, and there is no known means of recovering it once it has hardened. The supply of copaltite on board ship should be kept as small as practical and frequent requisition placed for new supplies. The material should be kept in as cool a location as practicable.

When casing joint compounds are applied to turbine flanges, care must be taken to avoid excessive amounts. It must be remembered that, in addition to being squeezed out at the outside edge of the joint, the sealing compound will also be squeezed out at the interior edge of the flanged joint. Due to close clearances, the turbine blading will strike or rub against any excessive amounts of compound on the inside of the turbine. Although no damage may be done to the blading, there will be an abnormal noise inside the turbine for a short period of time when the turbine is started for the first time after repairs have been made.

Care should be taken that the joint compound is not forced into the grooves designed for pumping in a sealing compound. These grooves should remain open when the turbine casing joint is bolted down. If the compound enters these grooves, it will harden and may prevent future pressure pumping if this standby method of stopping casing joint steam leaks becomes necessary.

## Bolting of Casing Joints

With high steam temperatures and pressures, and because of higher stresses involved, it is difficult to make the horizontal joint bolting, when cold, sufficiently tight by using sledging or extension wrenches only. Therefore, bolts should be given an additional stress by heating. Practically all horizontal joint bolts of cruising and high-pressure turbine casings are drilled their full length for the application of heat. Heat may be applied by using an acetylene torch or electric heating units. A special attachment should be fitted

to an acetylene torch. The recommended dimensions of this attachment, as well as the suggested type of flame and mixture of gases, are shown in figure 2–17.

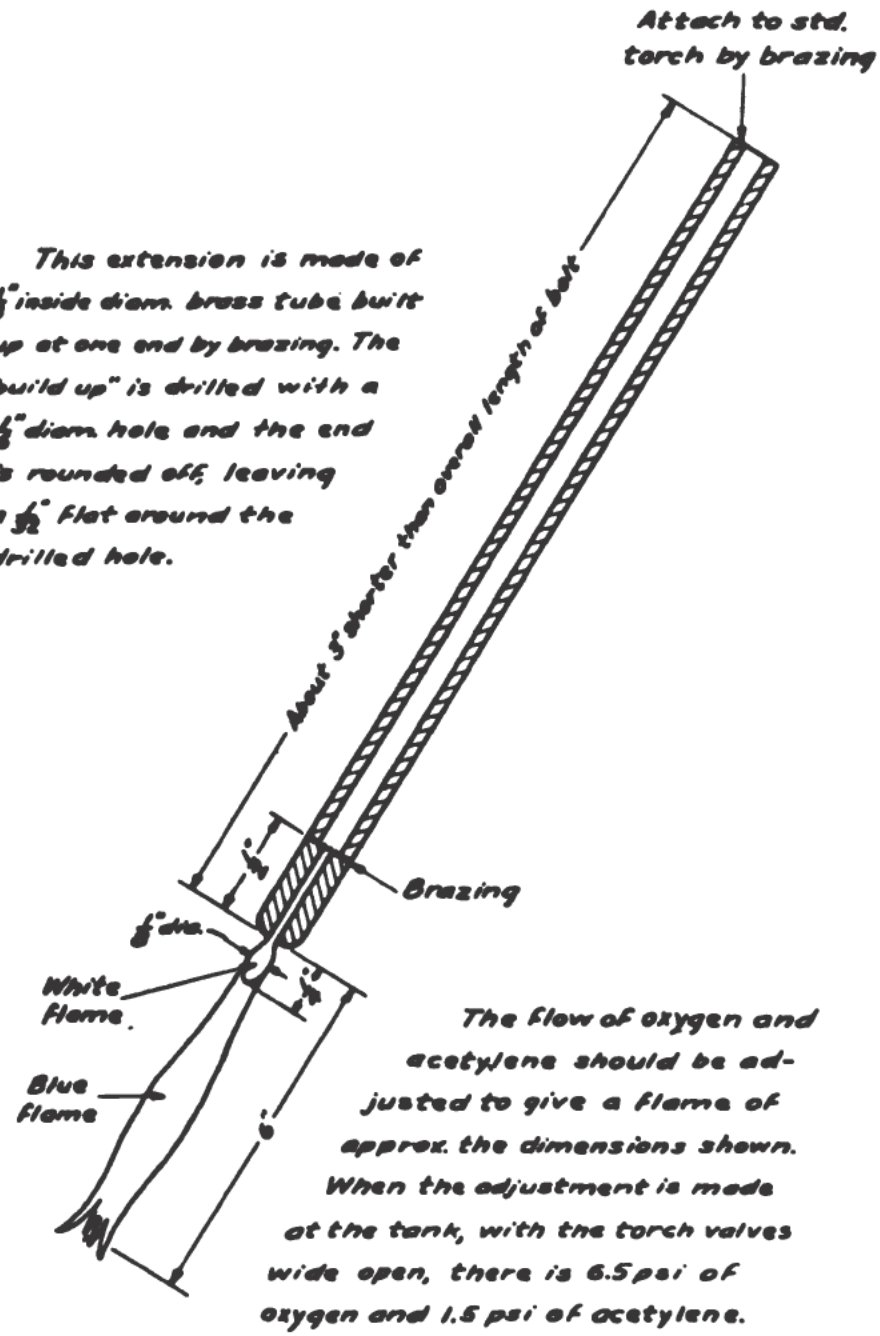



**Figure 2–17.—Acetylene torch tip for heating bolts.**

When the heat is applied, the flame should be moved up and down in the bolt to equalize the heating. Depending on

the lengths and diameters of the bolting, 4 to 6 minutes are usually required for the heating, until the nuts can be tightened in accordance with the manufacturer's instructions. Care should be taken not to overheat and tighten the bolts more than required.

In order to prevent galling, all threads should be thoroughly cleaned and lubricated before installation. Lubricants that have been found satisfactory are Crane Valve Co. thread lubricant No. 425, and a mixture of two parts graphite with one part red lead thinned to heavy paint consistency with boiled linseed oil (G. E. Compound D50A22).

The bolts should be tightened to a stress specified by the manufacturer (about 40,000 psi). Direct measurement of the extension or elongation of the bolt is the most certain way of knowing the stress. This can be accomplished by measuring the increase in the over-all length of the bolt. When this is equivalent to 0.0013 inch per inch of over-all length, the stress will be approximately 40,000 psi. Suitable devices for direct measurement can be made for measurement through the holes in the bolts and nuts. Figure 2–18 shows a suggested device where the hole in the nut is the same as the hole in the bolt, and figure 2–19 shows where the hole in the nut is larger than the hole in the bolt.

All bolts should first be tightened cold to bring the flanged joint together solid. Each individual bolt is then loosened and installed handtight with a wrench. Care should be taken that there is a minimum length or clearance of 1/16 inch between each end of the bolt and the inside end surface of each nut, as shown in figures 2–18 and 2–19. A measurement of the length of each bolt is taken and recorded. The bolt is heated for approximately 5 minutes. The upper nut is then sledged until the length of the hot bolt reaches the proper length as specified by the manufacturer. This procedure is repeated until all the bolts have been tightened. It is a good policy to check the readings when all bolts have been installed and have reached room temperature. These readings should check with the cold reading as specified by the manufacturer.

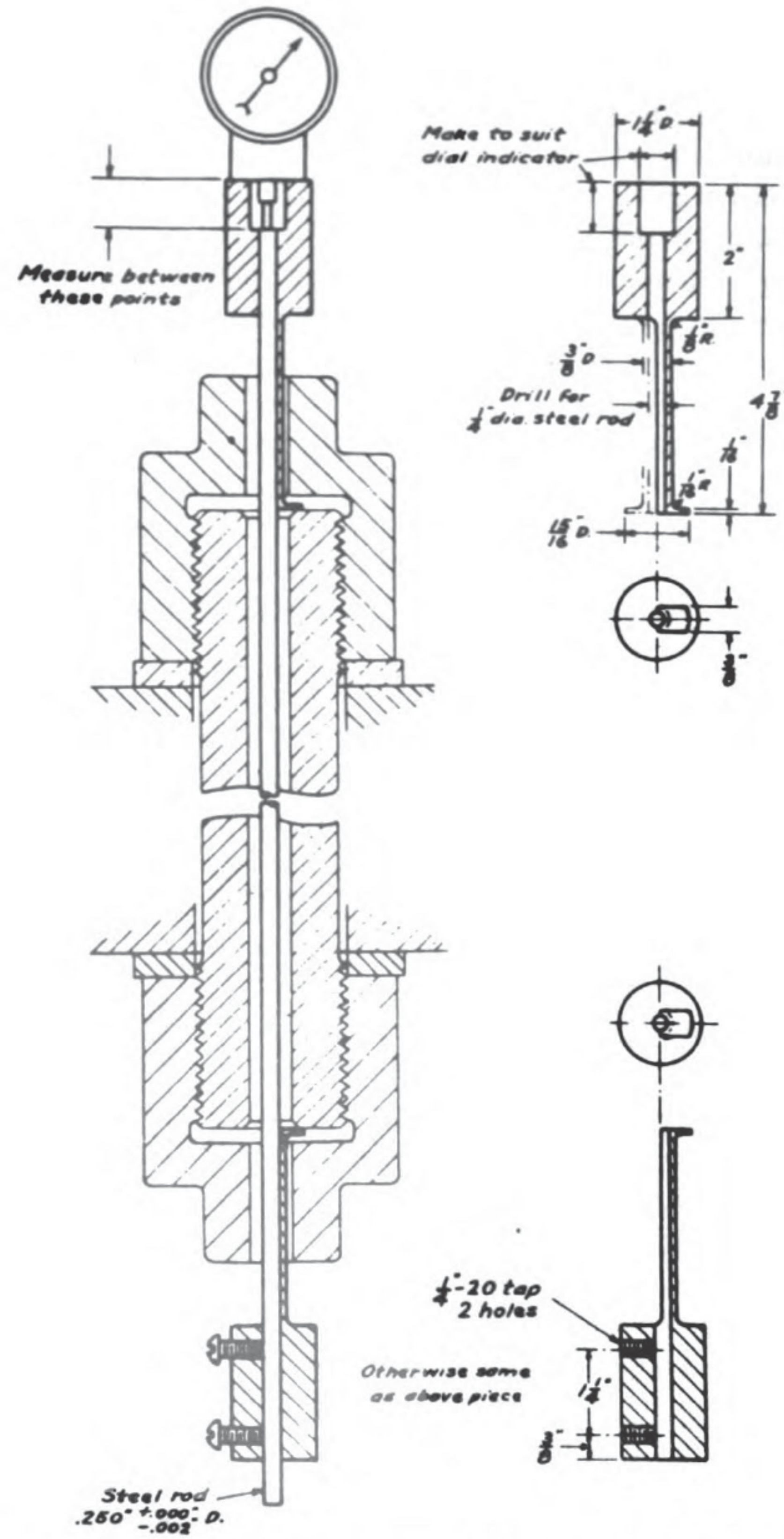



**Figure 2–18.—Device for measuring elongation of bolts (hole in nut is same size as hole in bolt).**

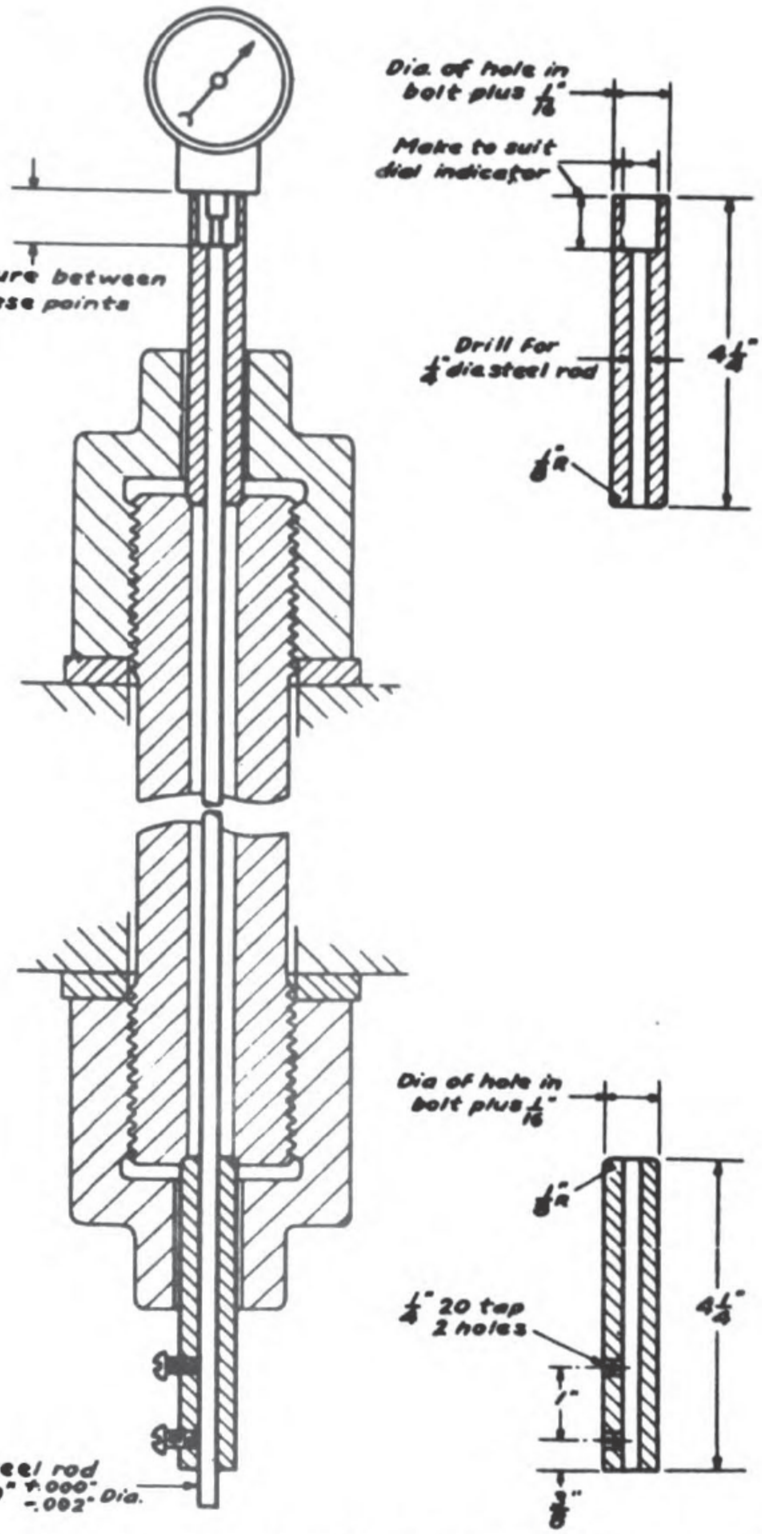



Figure 2–19.—Device for measuring elongation of bolts (hole in nut is larger than hole in bolt).

If it is desired to tighten bolts without using the measurement method just discussed, another method may be used. This approximate method requires that the bolt be tightened by turning the nut a given number of flats from the handtight position. To assure that any warpage of the flanges is taken up or any excess sealing compound squeezed out, all bolts should be sledged reasonably tight. Each bolt should then be loosened and retightened, one at a time, as follows:

1. Pull up cold with hand wrench 48-in. long for 2¾-in. bolts; a 36-in. wrench for 2½-in. bolts; a 24-in. wrench for 2¼-in. bolts; and an 18-in. wrench for 2-in. bolts.
2. Mark the nut position at both ends of the bolt.
3. Apply heat.
4. Pull up the top nut one flat for each 10 inches of overall bolt length.

### Report of Lifting

Whenever turbine casings are lifted, the agency doing the work should take and record all turbine measurements and clearances before and after repairs. Before repairs are made, bladed tip clearances may be omitted if the repair activity considers them as unnecessary. The record should also include the material condition of all parts revealed when opened and the repairs made. The activity doing the work should forward this report to BuShips, and should send copies to the vessel concerned and to her home yard. If the work has been accomplished by a tender or repair ship, a copy of the report should be forwarded to the ship's home yard for record. In any event, the ship should copy all the pertinent data from the report onto the Machinery History Card for future reference.

### Required Overhaul Checks

Some of the important points (see fig. 2–20) to be checked during a major overhaul of a propulsion turbine are as follows:

1. HIGH-PRESSURE BUCKETS. Scale may be found here. If it is, it may be removed by washing with water. Some

scale must be scraped off mechanically—with emery paper.

2. Low-Pressure Buckets. Water cutting may have occurred here, particularly at the entrance edges near the bucket tips. If the tips are deeply eroded, it may be necessary to install new buckets. If the buckets are not replaced, the amount of the erosion, which can be measured by using a straightedge and a feeler gage, should be recorded for comparison at the next inspection.

3. Water Drainage Orifices. If the low-pressure blades have sustained severe water cutting, these orifices will probably be found to be plugged so that they do not drain properly. The orifices should be cleaned out thoroughly in order to prevent water from backing up and causing further cutting of the buckets.

4. Diaphragm Joints. Flow marks will be evident if there is leakage across the diaphragm joints. Such leakage usually indicates that the diaphragm is not properly seated, or that a new joint key is needed. In severe cases, welding and machining repairs may be necessary.

5. Rotor Clearance. This should be measured and checked against the manufacturer's original tolerance. In unusual or isolated cases, the clearance of the rotor may be readjusted by means of two shims locating the thrust bearing inner casing. This work should be done by a shipyard with the approval of the manufacturer's representative.

6. Bearing Clearances. If the clearance of the bearings is near or greater than the manufacturer's tolerance, the bearings should be rebabbitted. Spares should be installed only in an emergency.

7. Packing Rings. Excess leakage may be taking place if the packing clearance is considerably greater than the manufacturer's tolerance. In this case it is best to install new packing rings to restore the original clearance.

8. Casing Interior. If erosion is found here, it may be necessary in some cases to make repairs to the eroded parts, which sometimes can be metallized to restore as well as protect their surface.

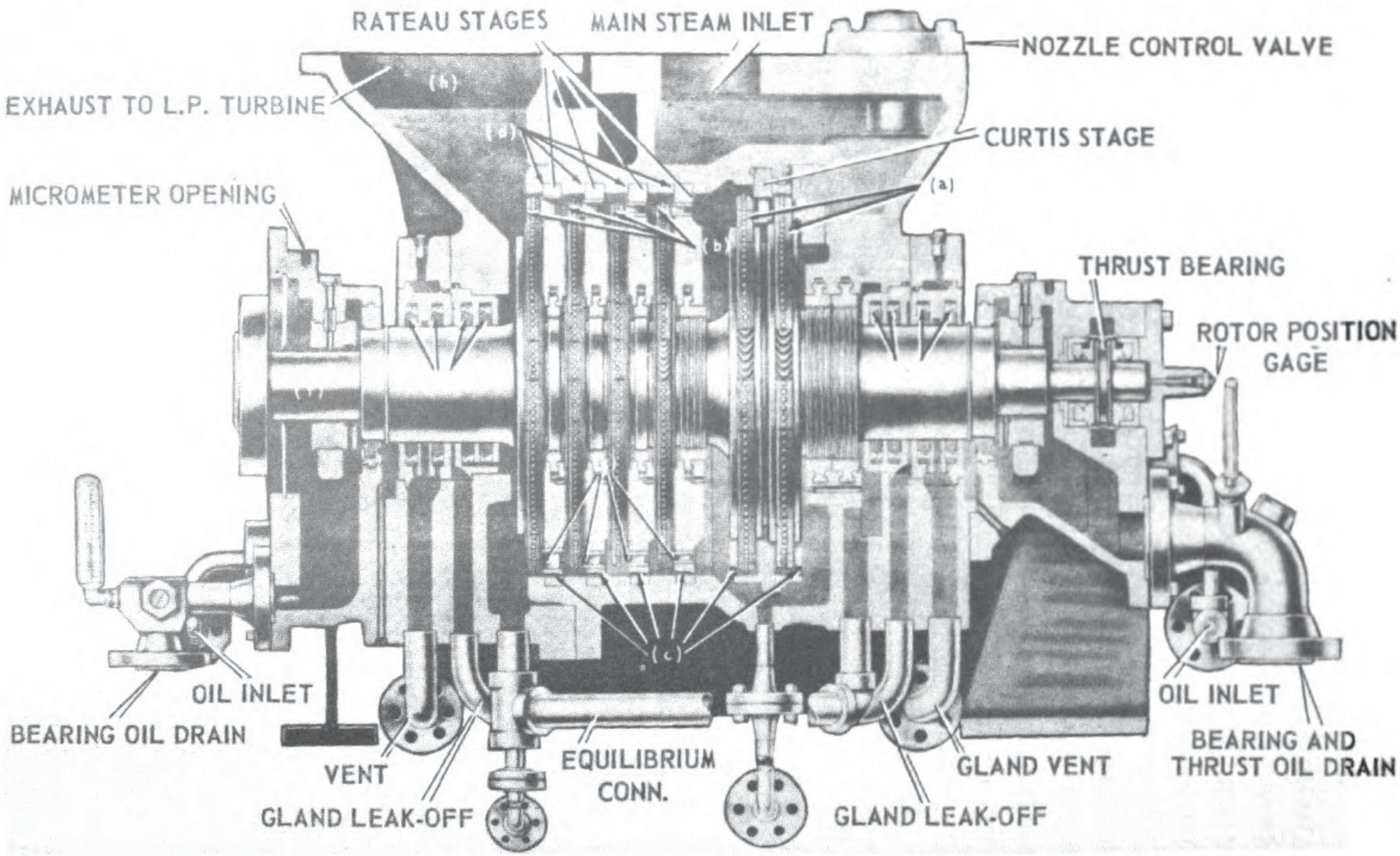



**Figure 2-20.—Required overhaul checks.**

## SAFETY PRECAUTIONS FOR TURBINES

The following safety precautions for propulsion turbines are prescribed by BuShips and should be observed:

1. Do not use auxiliary steam for warming up the main turbines.
2. Be sure that the lubrication system is in operation before turning over the main engines.
3. Keep the rotors turning over continuously while warming up the main engines.
4. Never fail to investigate any noise emanating from a turbine.
5. Do not put way on the ship when turning over the main engines.
6. If a turbine vibrates, slow it down, investigate, and endeavor to locate the cause.
7. Except in an emergency, do not admit steam to an astern turbine until the steam to the ahead turbine has been secured, and vice versa.
8. In getting under way, be sure that all steam lines are properly drained.
9. When steam pressure drops, do not open the throttle to such an extent that the operating pressure of the steam is brought to a dangerously low point.
10. Stop the engines immediately if the oil supply fails.
11. If the throttle valve sticks, close the guarding valve as soon as possible. In an emergency, the guarding valve may be used to operate the ship.
12. Exercise care to prevent the entry of foreign matter into a turbine when it is opened for inspection.
13. Close the turbine drains about 24 hours after securing, and when the turbine is thoroughly cooled.

## SUMMARY

In order to perform your job effectively, you should be familiar with the operation, required maintenance, and repair procedures for propulsion turbines. Refer to the manufacturer's instruction books for the installation in your

ship so that you may have detailed information on the turbines.

Know what precautions must be taken with regard to the turbines and how to investigate causes of the more common operating difficulties.

Remember that the oil clearances of the journal and thrust bearings are required to be checked at regular intervals and the readings permanently recorded on the Machinery·History Bearing Record Cards.

Under normal conditions, all major repairs of main turbines will be accomplished by naval shipyards or by other repair activities. Even though the MM1 or C may not perform major repairs himself, he should have a general knowledge of all types of repairs made to turbines. Also, for his own ship's installation he should have a good understanding of the types of repairs which should be accomplished by the ship's force; those which should be performed by repair ships; and those which require shipyard facilities.

As an MM2 you had to be familiar with general construction, operations, and routine maintenance of turbines. As an MM1 or C, your duties will require additional information on turbines, particularly in regard to inspections, maintenance, trouble-shooting, and repairs. Detailed information on the main turbines of your ship will be necessary if you are to properly supervise personnel and perform certain duties related to the maintenance and repair of turbines.

## QUIZ

1. Why are most turbines equipped with needle valves?
2. Under any operating condition, the maximum temperature rise of oil passing through any bearing should not exceed how many degrees?
3. Bearing temperatures depend upon what factors?
4. If the temperature of a bearing increases above its normal running temperature, what should be checked immediately?
5. If a rumbling sound comes from a turbine when it begins to vibrate, what should be done?
6. The rubbing of turbine blading may result from what causes?
7. When a sharp metallic noise is heard after a rumbling sound in a turbine, what is the probable cause?
8. How often should nozzle control valves be visually checked for leaks?
9. How frequently should the interior of main turbines be inspected?
10. How frequently should the thrust bearing oil clearance be checked?
11. What clearance should be investigated if an axial position indicator shows an abnormal indication?
12. What source of information should be first consulted regarding maximum and minimum allowable oil clearances on turbine thrust bearings?
13. What should be done when a bearing surface is scored, or considerably worn?
14. What should be done when a thrust bearing collar is badly scored?
15. What determines the original end play of the turbine rotor?
16. Which personnel generally replace carbon shaft packing used on low-pressure main turbines?
17. What two compounds may be used for gunning grooves in turbine flange joints aboard ship?
18. Why are nozzle control valves more difficult to repair than any high-pressure steam valves?
19. What personnel generally make repairs which require the lifting of the turbine casing?
20. Depending on the size and type of turbine, how often should the main turbine casings be lifted?
21. Prior to making any recommendation concerning the lifting of main propulsion turbine casings, BuShips bases its decision upon what factors?
22. What procedure should be followed immediately after a turbine has been reassembled?

23. What material is used for sealing low-pressure turbine joints, or when the temperature is below 425° F?
24. If electrical heating units are not available, what equipment is recommended for heating horizontal flange bolts for high-pressure turbines?
25. Who is responsible for taking turbine clearances whenever turbine casings are lifted?
26. If a turbine vibrates, what procedure should be followed?
27. When should turbine drains be closed?

# CHAPTER 3

## MAIN REDUCTION GEARS

In order to understand the operation and maintenance of mechanical reduction gears aboard ship, the MM1 or C must be familiar with design principles and details of construction. To acquire this information, he should study the instruction books provided by the manufacturers of the different types of gears used by the Navy.

### REDUCTION GEAR TYPES

Single reduction gears (with speed reduction ratios as high as 20 to 1) give satisfactory results on the older plants, which utilize low-speed turbines. However, the high-speed turbines of modern installations require a higher speed reduction ratio. To eliminate the necessity of using excessively large main gears, the double reduction gear is employed.

Power to be transmitted is not the only factor in determining the type of reduction gear to be installed aboard a naval vessel. The space available, the weight involved, and the over-all plant economy must also be considered.

To meet the conditions of various installations three general methods of arranging double reduction gears for main propulsions have been developed. These arrangement methods employ helical gearing and are referred to as (1) articulated type, (2) nested type, and (3) locked train type.

## Articulated Gearing

As shown in figure 3–1, most articulated main reduction gears consist of three separate pinion and gear reductions. There are two high-speed sets, and one low-speed set, connected by quill shafts through the low-speed pinions. This type of gearing has more bearings and occupies more longitudinal space in the ship than the other two types of gears. For equal tooth pressures and reductions, therefore, it is heavier than the nested type. It is also larger and heavier than the locked train type gear of equal speed ratio.

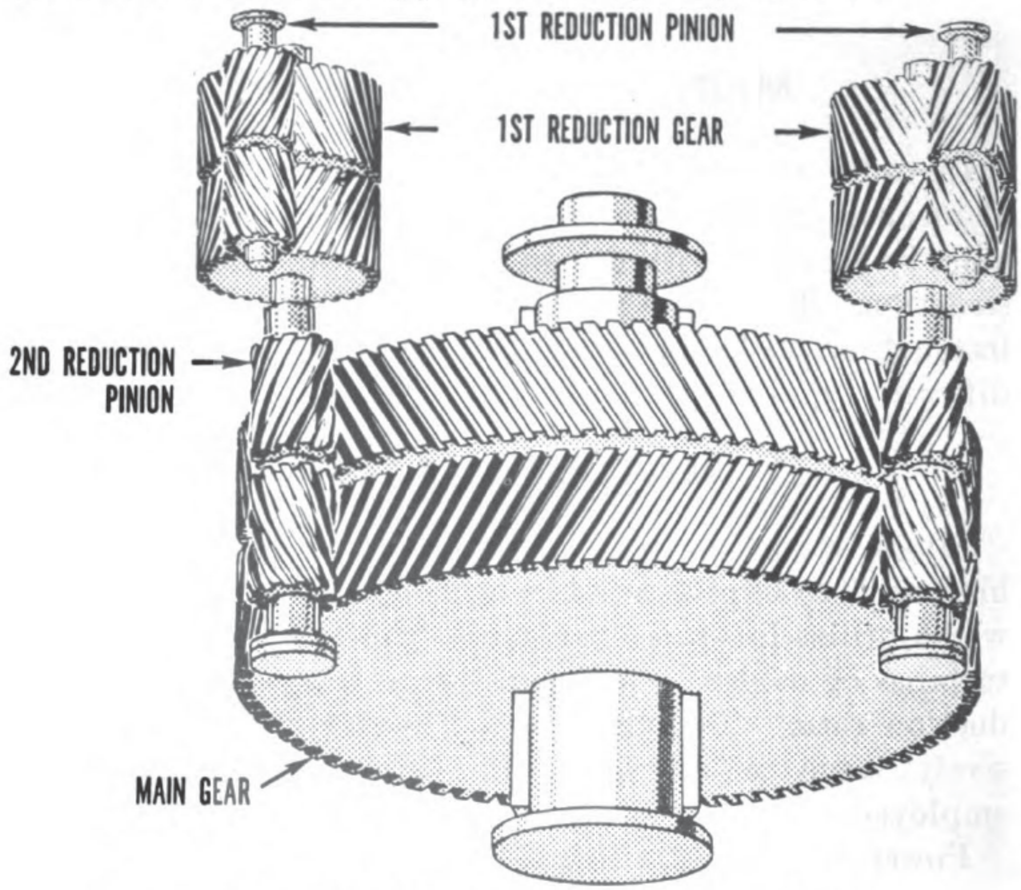



Figure 3–1.—Articulated type of double reduction gearing.

The articulated type of main reduction gears is used on steam-driven destroyer escorts and on some naval auxiliary ships.

## Nested Gearing

The nested type reduction gear is the simplest of all double reduction helical gearing. The nested gearing em-

ploys no quill shafts and uses a minimum number of bearings and flexible couplings. There is a minimum distance between the input and output coupling flanges. The helixes of the second reduction gear may be separated, with the first reduction gear between the second reduction gear rims, as shown in figure 3–2. In order to operate on both sides of the second reduction gear, the two helixes of the high-speed

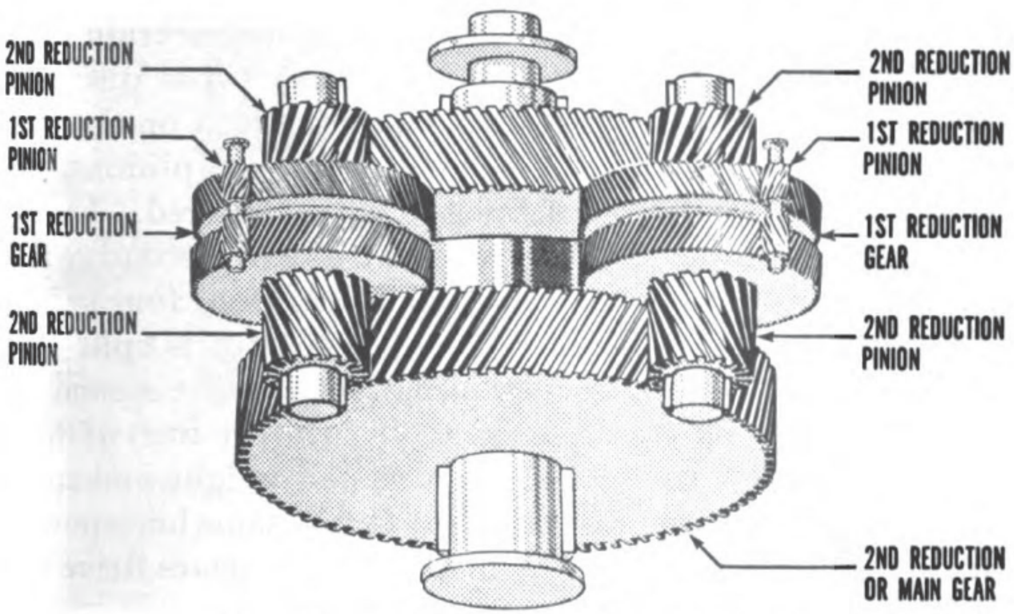



Figure 3–2.—Nested type gearing, with divided main gear.

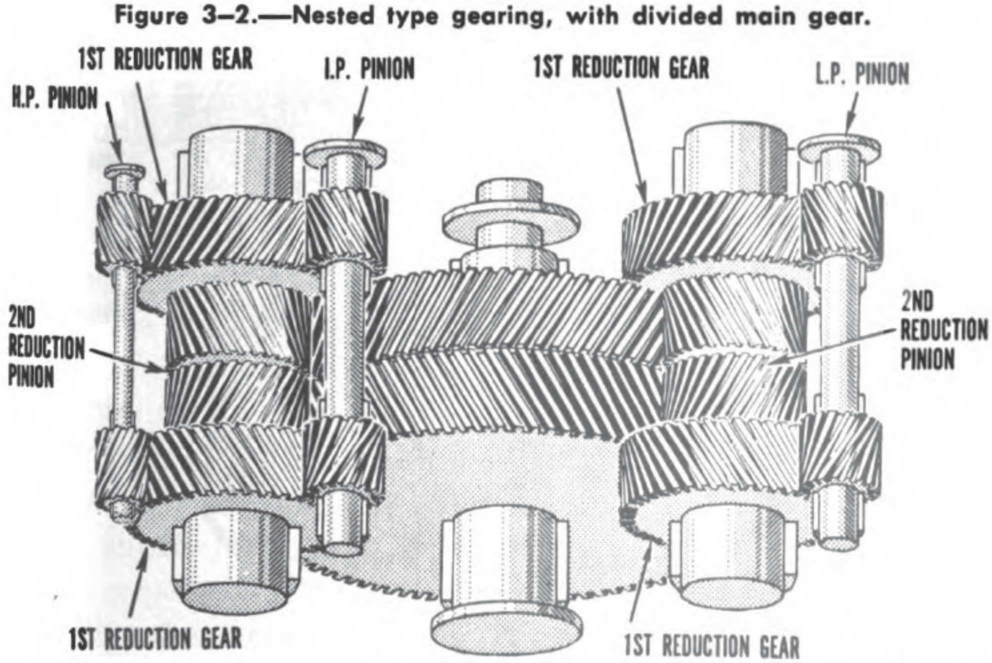



Figure 3–3.—Nested type gearing, with divided 1st reduction pinion and gear.

pinion and first reduction gear are separated, as shown in figure 3–3.

The nested type gearing is generally used on naval auxiliary or noncombatant ships.

## Locked Train Gearing

Greater amounts of power can be transmitted within limited space and weight requirements by the locked train gearing (fig. 3–4) than by either of the other types discussed above. To obtain an equal division of the load on the first reduction gear wheels and second reduction pinions, extremely accurate timing of the gearing is required. In this type of gearing, the power is transmitted to the second reduction gear through four first reduction gears and four second reduction pinions. Therefore, the power path is split four ways between the first reduction pinions and the second reduction gear. This reduces the tooth load per inch of face, and the locked train gearing requires less weight and space than other reduction gears designed for the same horsepower. In the locked train gear, the first reduction gears drive the

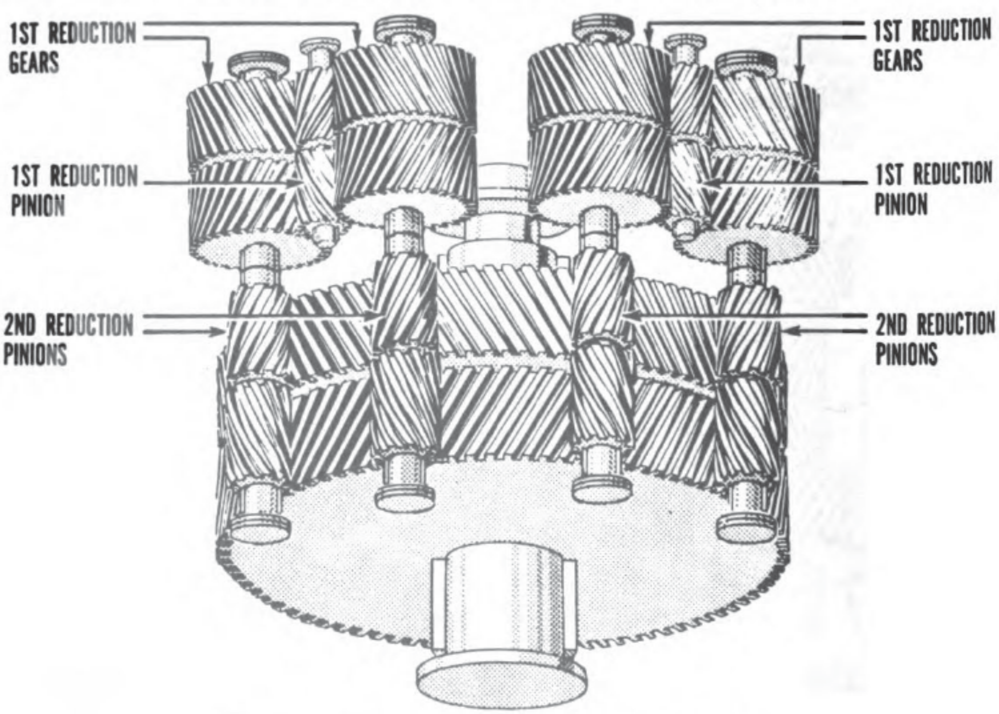



Figure 3–4.—Locked train type of gearing.

second reduction pinions through quill shafts which impart some flexibility to the design, both axially and torsionally.

Because of the cost of this type of gearing, its use can be justified only on ships employing large concentrations of power. Locked train, double reduction gears are used on all naval combatant ships (destroyers, cruisers, battleships, and carriers). Figure 3–5 shows the type of main reduction

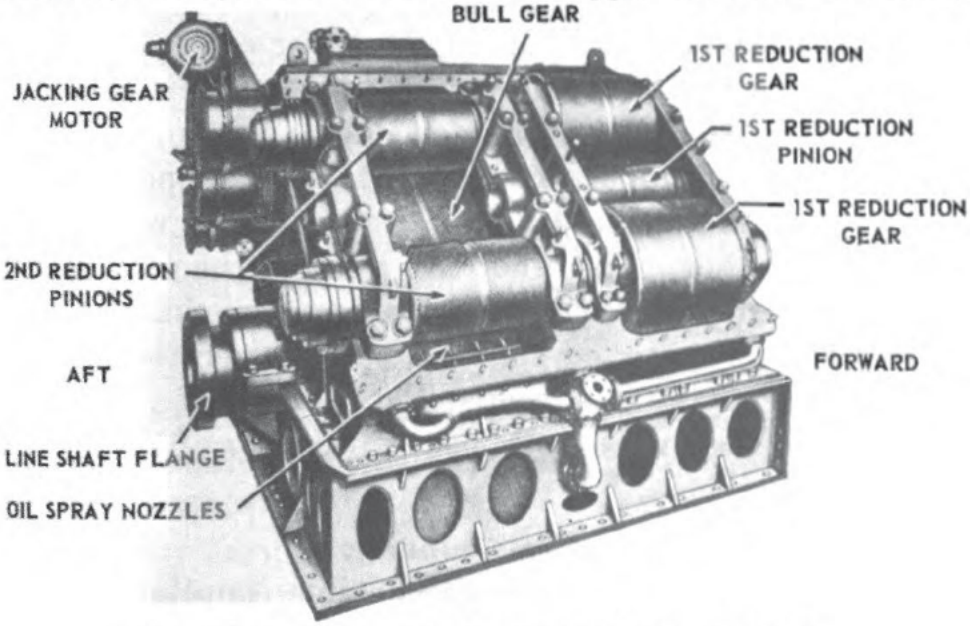



Figure 3–5.—Main reduction gear (locked train type).

gear used on destroyers. The reduction gears for larger ships are similar in construction, except that the low-speed pinions have individual bearing caps.

## GEAR CONSTRUCTION

Most gearing in use at the present time is of the double helical type, a right- and left-hand helix being employed to balance out the end thrust. The helical gear produces a smoother action and avoids the tooth shock of spur gears. The involute tooth contour is universally used because, with this type, the action of the teeth will be unimpaired in case the distance between the center lines of the gear and the pinion shafts is slightly increased by wear of bearings.

In most cases, all pinions are completely machined out of specially heat-treated nickel-steel forgings. The gear wheels are of built-up construction, with the teeth cut in

seamless steel circular bands which are welded to steel spiders. The first reduction gears are generally welded on their respective shafts. The bull gear is usually pressed on the shaft against a locating shaft shoulder, secured by one or more keys and locked, with a locknut, on the shaft.

### Gear Casings

The gear casing can be divided into four parts. The lower part is called the base section, or the lower case. It is used to support the bull gear, the main thrust bearing, and the upper parts of the main reduction gear. The intermediate section, called the upper case, supports the bearing housing for the intermediate speed pinions and gears, as well as the high-speed pinions. The other two parts of the gear casing are the main cover sections. The cover sections have inspection ports which are covered by easily operated hinged plates. These ports are so located that the teeth of any pinion or gear can be examined without the necessity of lifting the main cover sections.

### Flexible Couplings

In most Navy installations the flexible couplings are of the gear type in which power is transmitted through a float-

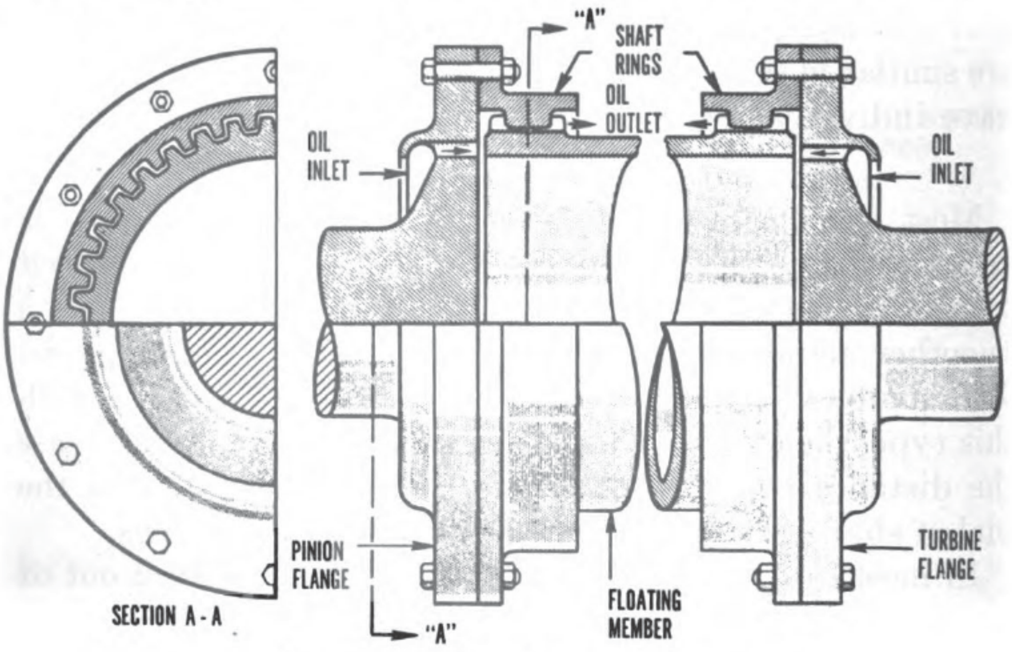



Figure 3–6.—Gear type coupling.

ing intermediate member with external teeth that mesh with the internal teeth of the driving and driven shafts.

Figure 3–6 shows the design of the gear-type flexible couplings that connect the main turbines to the high-speed pinions of the main reduction gear. The purpose of flexible couplings is to provide longitudinal flexibility between the driving and driven shafts, and thereby permit each shaft to be adjusted axially and to be held, by the thrust bearing of the turbine and the double-helical teeth of the pinion, in its proper position. The couplings also allow the expansion of the turbine shafts, and will take care of any slight misalignment between the main turbines and the reduction gears.

The design of the flexible couplings, which connect the first reduction gears and second reduction pinions, is shown in figure 3–7. In this case, a quill shaft of high torsional flexibility is used, as the floating member, to secure equal distribution of the load among the several elements of the gear train. The quill shaft runs inside the shafts of the intermediate speed gear and pinion rotors. By studying figure 3–7, it can be seen how flexibility is obtained between the 1st reduction gear and the 2d reduction pinion. Construction details of the flexible coupling are shown more clearly in figure 3–6.

A flexible coupling is installed in the shaft between the cruising turbine reduction gear and the high-pressure turbine. Figure 3–8 shows a flexible coupling which is used on destroyers. In this coupling, the floating member is a transversely split sleeve, having internal teeth which mesh completely with the external teeth of the spur gears, mounted on the connected shaft ends.

As far as the lubrication of flexible couplings is concerned, steady streams of oil from the supply passages of the adjacent bearings are directed into the coupling when the reduction gears operate. The oil is caught in the faces of the coupling flanges (shown in fig. 3–6). Centrifugal action forces oil through the horizontal holes in the flanges to the coupling gear teeth. Oil is discharged from the teeth into coupling guards and then flows into the oil drain system.

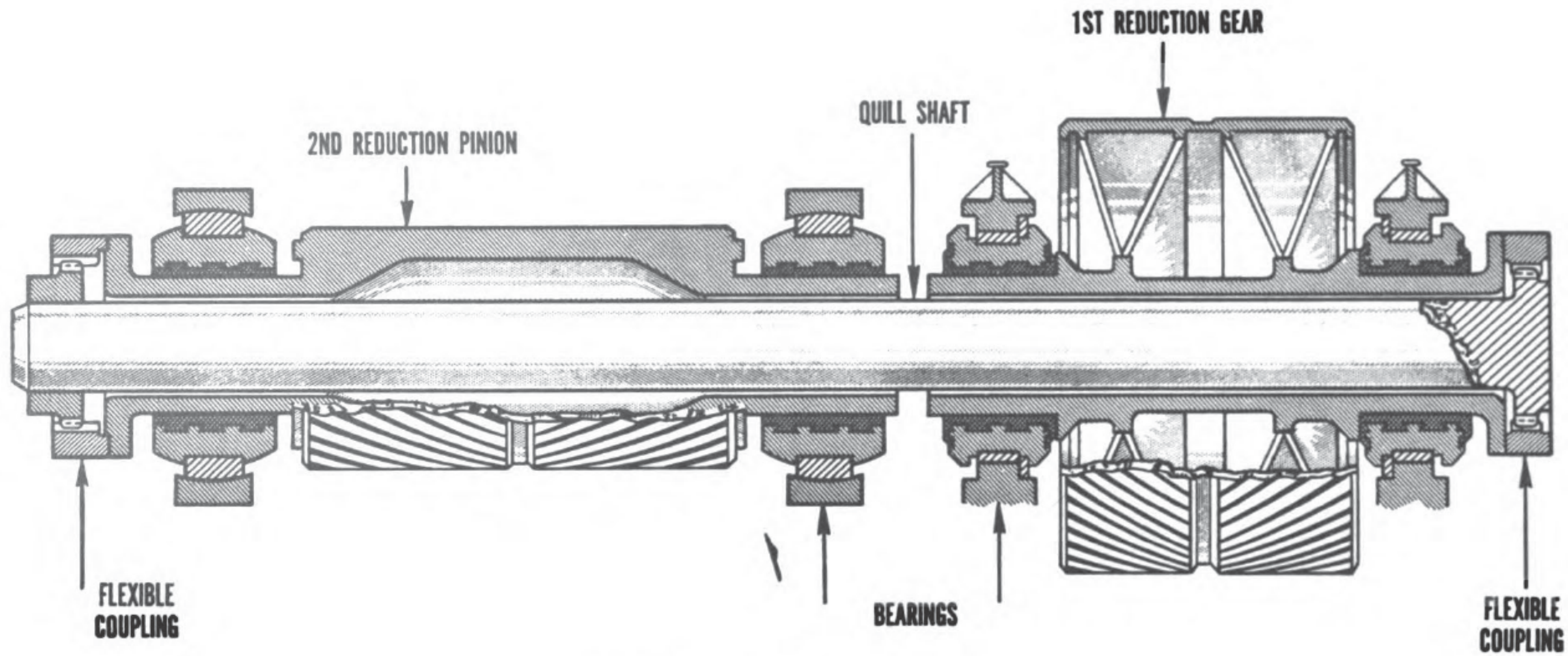



Figure 3–7.—Quill shaft assembly.

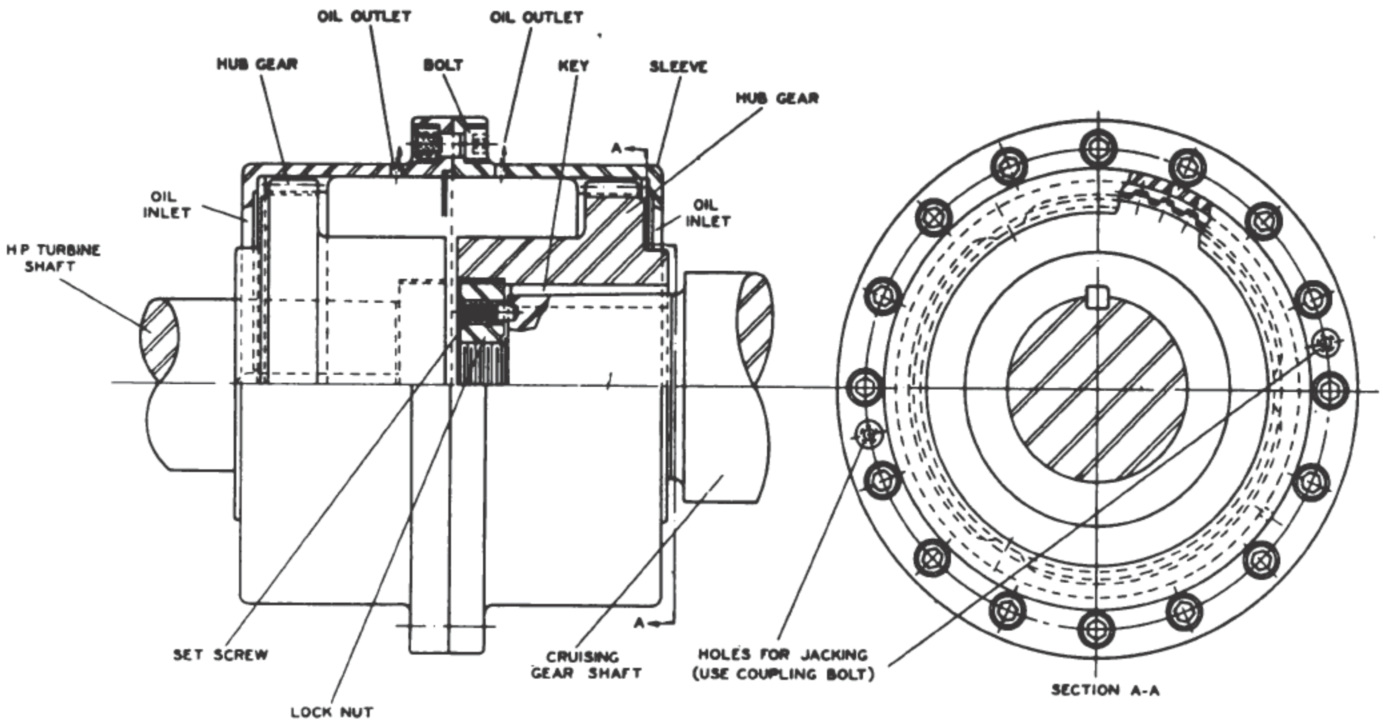



Figure 3-8.—The flexible coupling between the cruising gear and high-pressure turbine.

## EFFICIENT LUBRICATION OF GEARS

The efficient lubrication of reduction gears is of the utmost importance. It is essential that oil at the designated working pressure and temperature be supplied to the gears at all times while they are being turned over, either with or without load. Navy symbol 2190T lubricating oil is used for the main reduction gears as well as for turbines. The use of clean, pure oil is essential to long life and successful operation of the gears.

Oil must be free from all impurities, such as water, grit, and metal particles. Particular care must be taken to clean out metal flakes and fine chippings when new gears are wearing into a working fit. Lint or dirt, if allowed to remain in the system, will clog the oil-spray nozzles. Spray nozzles must be kept open at all times. Oil-spray apparatus, fitted for the lubrication of gears, should not be altered without the authority of BuShips.

Although the lube oil strainer performs its function satisfactorily, it cannot trap the very fine particles which pass through the mesh; the magnet doesn't get all the metal particles. Fine particles of metal and dirt may become embedded in the babbitt of bearings, causing scratches and wear on journals. Large particles of metal or dirt, when passing through, may score the babbitt and journal. This fine abrasive passing through the gear mesh acts like a lapping compound, removing metal from the reduction gear teeth. Clean oil must be maintained by proper purification.

### Effects of Acid and Water in Oil

Water in the oil is extremely dangerous. Even small amounts soon cause pitting and corrosion of the teeth. Acid is equally dangerous. The oil must be tested frequently for water, and periodic tests should be made for acid content.

The importance of taking immediate corrective measures when salt water is found in the reduction gear lubricating oil system cannot be emphasized too strongly. Occasionally gross contamination of the oil by salt water occurs when a

cooler leaks or when leaks develop in a sump which is integral with the skin of the ship.

The immediate location and sealing of the leak or removal of the source is not enough. Steps must also be taken to remove the contaminated oil from all steel parts. Several instances are known where, because such treatment was postponed (sometimes for a week or less), gears, journals, and couplings became so badly rusted and pitted that it was necessary for naval shipyard forces to remove the gears and recondition the teeth and journals. Burned-out bearings have resulted from salt-water contamination of the lubricating oil.

Water, generally due to condensation, is always present in small amounts. Air which enters the units contains moisture. This moisture condenses when it strikes a cooler object and subsequently mixes with the oil. The water displaces oil from metal surfaces and causes rusting. Water reduces the lubricating value of the oil itself. Lubricating oil must be maintained in good condition by the proper use of the purifier and settling tanks.

When the main engines are secured, the oil should be circulated until the temperature of the oil and of the reduction gear casing approximates the ultimate engineroom temperature that will be attained. While the oil is circulated, the cooler should be operated and the engine should be jacked continuously. The purifier should also be operated while the oil is being circulated, and after circulation until water is no longer discharged from the purifier. This procedure will eliminate condensation from the interior of the main reduction gear casing.

If the purifier does not operate satisfactorily and have the correct water seal, it will not separate water from the oil. An additional check for the presence of water can be made by taking small samples of oil, in bottles, and allowing the samples to settle over a period of time. In taking oil samples, a routine procedure should be followed.

Samples of lubricating oil should be tested at a naval shipyard, or similar activity, for acid, water, and sediment

content. Ships should take advantage of every opportunity to have laboratory tests made of the lubricating oil. When the neutralization number exceeds 0.50 the lubricating oil should be replaced.

The supply of oil in the system should be replenished immediately after the oil has been renovated. The amount of lubricating oil in the sump should never be allowed to drop below the minimum allowable level. An adequate reserve supply of clean oil should always be maintained.

### Formation of Oil Emulsion

With continuous use, the lube oil will increase in acidity, and the free fatty acids will form a mineral soap which reacts with the oil to form an emulsion. Once oil has emulsified, the removal of water and other impurities becomes increasingly difficult. Even more important, however, is the fact that as the oil emulsifies it loses its lubricating quality. The formation of a proper oil film is then rendered impossible, and it will be necessary to renovate the oil.

It sometimes happens, when a ship from the reserve fleet is placed back in commission, that the rust preventive compound is incompletely removed. The residue of this compound may cause serious emulsification of the lubricating oil. Operating with emulsified oil may result in wiping of the bearings, or in other damage to the reduction gears and turbines. Since it is extremely difficult aboard ship to destroy emulsions by heating, settling, and centrifuging, a close check should be made to see that such emulsions do not occur. At the first indication of an emulsion, the plant should be stopped and the oil renovated.

### Level of Oil in the Sump

Lubricating oil is supplied to the gears from the main engine lubrication system, with a connection to each bearing and with nozzles so located that a constant stream of oil is directed within the gears. This contact stream of oil, over the gears, not only lubricates the gears but also produces

a cooling effect therein. Since the reduction gears are located directly above the lubricating oil sump tank, positive means should be taken to ensure that the bull gear will not dip into the oil. The normal oil level in the sump extends above the bottom of the bull gear. A sheet-metal shield, sometimes called an oil-excluding pan, is fitted around the lower half of the bull gear casing. If the gear is allowed to dip into the oil, the churning action of the gear will cause the oil to foam and to heat up. Under normal conditions, only a small quantity of oil comes in contact with the bull gear; and therefore no dangerous vibration and no churning effect can be produced. Oil from the gears is swept out of the pan by the bull gear and drained into the sump.

When there is too much oil in the sump, the gear will churn and aerate the oil, causing a sudden increase in temperature. If this occurs, the engines must be slowed or stopped until the excess oil can be removed and normal conditions restored. Routine checks should be made to see that the lubricating oil is maintained at the proper level. Any sudden loss or gain in the amount of oil should be immediately investigated.

## LOCKING AND UNLOCKING THE MAIN SHAFT

In an emergency, or in the event of a casualty to the propulsion machinery of turbine-driven vessels equipped with more than one shaft, it may be necessary to lock a propeller shaft to prevent damage to the machinery. Engaging the turning gear and then applying the brake is the simplest and most expeditious means of locking a propeller shaft while under way.

### Locking the Propeller Shaft

Personnel should be trained, by means of actual drills, in the proper procedure of locking and unlocking the main shaft. Sufficient trained personnel should be available so that the procedure used to engage and disengage the turning gear while under way can be carried out carefully and expeditiously. BuShips requires the following procedure:

1. Reduce the ship's speed to approximately one-half full power speed or less. In case a ship has been slowed down, the speed should not be changed.

2. Close the ahead throttle and open the astern throttle. Keep the latter open until the main shaft is stopped and remains in a stationary position.

3. Record the rpm on the operating shaft(s) and the astern chest steam pressure on the stopped shaft.

4. Engage the turning gear (see that the main shaft is NOT moved) and immediately clamp the turning gear motor shaft brake.

5. Close the astern throttle slowly. (The jacking gear should be observed for any possible movement.)

6. Indicate, by means of a warning sign or an indicator device at the main throttle board, that the shaft is in locked position.

7. Record the time when the main shaft was stopped.

During drills, the main shaft should NOT remain in locked position longer than 5 minutes, if possible.

The ahead throttle should NOT be opened when the turning gear is engaged; to do so would damage the turning gear, since the torque produced by the ahead turbines is in the same direction as the torque of the locked propeller shaft. A warning sign should be placed at the ahead throttle. This is done to prevent accidental opening of the throttle with the turning gear engaged.

The maximum safe steaming speed with a locked propeller shaft should be known. Additional information regarding the safe maximum speed that your ship can steam with a locked propeller can be obtained from a table in chapter 41 (article 41–130) of BuShips *Manual*.

### Unlocking the Propeller Shaft

The recommended procedure for unlocking the main propeller shaft is as follows:

1. Reduce the temperature of the main steam as much as practicable by reducing the superheat.

2. Note the length of time that the shaft has been in locked position (see step 7 in the shaft locking procedure).

3. Bring the operating shaft(s) to the same rpm recorded in step 3 of the shaft locking procedure. When necessary, allow time for the ship to settle down at this speed.

4. Open the astern throttle of the locked shaft until the astern chest steam pressure equals the value recorded in step 3 of the shaft locking procedure.

5. Apply a steady disengaging force to the clutch lever and slowly open the astern throttle until the clutch disengages.

6. Slowly close the astern throttle, after the turning gear is disengaged.

7. Release the brake on the turning gear.

8. Remove the warning sign or change the indicating device at the main throttle board (see step 6 of the shaft locking procedure).

9. Open the ahead throttle and slowly bring the main shaft up to the speed required for the operation of the ship.

CAUTION. If the shaft has been in locked position more than 5 minutes, the turbine rotors may have become bowed, and special precautions must be taken when unlocking it. The procedure outlined in the following paragraphs is recommended:

Before the shaft is allowed to rotate, men should be stationed at the turbines to check for any abnormal vibration and listen for any unusual noises or sounds.

When the turning gear has been disengaged, the astern throttle valve should be slowly closed. This action will allow the shaft to turn because of the torque produced by the propeller passing through the water. If vibration indicates a bowed rotor in one of the turbines, the shaft should be immediately stopped, or slowed, by means of the astern throttle valve.

If the operation of the ship at such a slow speed is not practicable, another procedure for straightening a bowed rotor must be followed. The affected shaft should be braked

by using the astern throttle to reduce the turbine speed to the point of little or no vibration. During this interval the ahead throttle valve should be cracked to permit some steam flow in the ahead direction. This will aid in the warming up and straightening of the shaft. In order to avoid having an excessive exhaust temperature, it is desirable to have a low steam temperature.

As the vibration of the rotor is reduced, the astern valve should be closed gradually in order to allow the rotor speed to increase. When the vibration disappears, the astern valve should be closed. The turbines are now ready to operate in a normal manner.

## ABNORMAL SOUNDS AND VIBRATION

On multishaft turbine-geared vessels, unusual noise may occur at low shaft rpm when maneuvering or during passage in very shallow water. These noises do not result from any defect in the propulsion machinery and will not occur during normal operation. A rumbling sound which occurs at low shaft rpm is generally due to the low-pressure turbine gearing floating through its backlash. The rumbling and thumping noises which may occur during maneuvering, or during operation in very shallow water, are caused by a torsional vibration initiated by the propeller.

Noises referred to above are characteristic only of some units and should be regarded as usual sounds for these units. These sounds will disappear with a change of propeller rpm or when the other causes mentioned above are no longer present. The noises can usually be noticed in destroyers when the engines are reversed and the ship is backing slowly in ground swells or in a choppy sea.

### Abnormal Sounds

A properly operating gear has a definite sound which the trained operator can easily recognize. At different speeds and under various operating conditions, the operator should be familiar with the normal operation of the gears aboard his ship.

In the event of any abnormal sounds or noises, an investigation should be made immediately. In making an investigation, a great deal will depend upon how an experienced operator interprets the sound or noise heard.

The readings of lube oil pressures and temperatures may or may not be of any assistance in determining the reason(s) for abnormal sounds. A burned-out high-speed pinion bearing, or a burned-out main thrust bearing, can be detected by a rapid rise in oil temperature for the individual bearing. A certain sound or noise may indicate misalignment or improper meshing of the gear teeth.

In either of the above-mentioned cases (a burned-out bearing or trouble with the gear teeth), the main propeller shaft should immediately be stopped and locked. An inspection should be made to determine the cause of the abnormal sound or noise. The trouble should be remedied before the reduction gear is placed back in operation.

In the case of a normal operating reduction gear having unusual noises caused by conditions which are minor in nature, the gear should be operated cautiously and under close supervision by experienced personnel. An investigation should be made, as soon as practicable, to determine the cause of the unusual noise. Upon discovery of the trouble, appropriate action should be taken to remedy the condition.

### Vibration

If the main reduction gear vibrates, a complete investigation should be made, preferably by a naval shipyard. Vibration is caused by bent shafts, by damaged propellers, and by improper balance. It must be remembered that when the units are built, the gear wheels are carefully balanced (both statically and dynamically). Unbalance in the gear is manifested by unusual vibration and noise, or by unusual wear of bearings.

A sudden or gradual vibration in a reduction gear that has been operating satisfactorily for a long period of time can generally be attributed to a cause outside of the reduction

gear. The turbine rotors, rather than the gears, are more likely to be out of balance.

In cases where the ship has been damaged, vibration of the main reduction gear may result from misalignment of the turbine, the main shafting, or the main gear foundation.

When vibration occurs within the main reduction gear, trouble or damage to the propeller should be one of the first things to be considered. The vulnerable position of propellers makes them more liable to damage than other parts of the main plant. Bent or broken propeller blading may transmit vibration to the main reduction gear. Propellers also may become fouled with line and steel cable.

## MAINTENANCE OF REDUCTION GEARS

Under normal conditions, all repairs and major items of maintenance work on main reduction gears should be accomplished by a naval shipyard. When the services of a shipyard are not available, emergency repairs should be accomplished (where possible) by a repair ship or advanced base. Minor inspections, checks, and repairs should be accomplished by the ship's force.

### Material History

It is of utmost importance that the Material History contain a complete record of the installation from the time of commissioning. Complete installation data as furnished by the contractor should be entered on the Machinery History Cards by the ship's engineering personnel when the ship is at the contractor's yard. This should include the crown thickness readings and the clearances of the original bearings, the thrust settings and clearances, and the backlash and root clearances for gear and pinion teeth. It is essential that this information be available when the alignment is subsequently checked.

An accurate record of all repairs, adjustments, readings, and casualties should also be kept on the Machinery History Cards.

All original bearing data, as well as all routine bearing measurements, should be entered on the Bearing Record Card of the Machinery History. A separate card is made out for each main thrust bearing.

### Bearings

Under normal conditions, the main reduction gears will not need new bearings or other repairs for an indefinite period. If abnormal conditions or bearing casualties occur, the naval shipyards will generally perform all major repairs and adjustments. In emergencies, other than when major damage to the gears themselves has resulted, repair ships and tenders, or advanced repair bases, may make the necessary repairs.

Approximately 50 percent of the number of bearings installed in the main reduction gear are carried as spares. Usually each bearing of the above groups is interchangeable and may be used for either the port or starboard gear set.

Special tools and equipment are normally provided on board ship for (1) lifting the main reduction gear covers, (2) handling the pinion when removing or replacing pinion bearings, (3) making the required measurements, and (4) rebabbitting bearings (on large ships).

The special tools and equipment should be available aboard ship in case repairs have to be made by repair ships or at advanced bases. The manufacturer's instruction book, which gives detailed information regarding repairs to be made to reduction gears, is also furnished aboard each ship.

Bridge gages are no longer used to check bearing wear of the main reduction gears. When necessary, the crown thickness method is used.

A bearing shell is classified as having a pressure-bearing half and a nonpressure-bearing half, when referred to the ahead position. The nonpressure-bearing half will have a radial scribe line at one end of the geometric center. The pressure-bearing half of all main reduction gear shells has three radial scribe lines on each end of the bearing shell. One of these scribe lines is located at the geometric center of



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the shell and the remaining line intersects the center scribe line at a 45° angle. This marking, on all service and spare shells, permits the spare shells to be marked at the factory and will be suitable for use on port and starboard gears.

The crown thickness of each shell at these points should be measured with a micrometer at 1¼ inches from the end of the shell. These measurements will be recorded during the initial alignment and should be permanently marked adjacent to each scribe line.

The amount of bearing clearance should not be allowed to become sufficiently great to cause incorrect tooth contact. The designed clearances for bearings are given in the manufacturer's instruction book. These clearances are also shown on the blueprints for the main reduction gears. In determining the maximum allowable clearance of bearings, chapter 40 of BuShips *Manual* can be used as a guide.

On a multishaft ship, if a main reduction gear bearing is wiped, the preferred procedure (if practicable) would be to secure the shaft and reduction gear until the units can be inspected and repaired by a repair activity.

By observing figures 3–5 and 3–7, it can be seen that it would be a major undertaking to replace bearings in the main reduction gear. In case of a casualty such as the loss of lubricating oil, the high-speed pinion shaft bearings are more apt to wipe than other main gear bearings. These shafts, which are coupled to the high-pressure and to the low-pressure turbines, will have a higher rotary speed than the other shafts in the reduction gear.

Assume, for example, that the after bearing for the outboard (lower) intermediate speed (2d reduction) pinion has been wiped because of an obstructed oil passageway. This would be the bearing on the left end of the shaft (or assembly) shown in figure 3–7.

Before attempting repairs, the first step would be to study the manufacturer's instruction book and blueprints for the reduction gear. The MM1 or C must have a clear understanding of the construction details and repair procedures

before starting a repair job, and be able to decide whether or not the repair work should be attempted. Other factors which must be considered are the location of the ship, the available Navy repair activities, and the operational schedule of the ship. In addition, a check is made to see that the required repair parts are on board.

In making repairs, the first step is to pump the lube oil from the sump. A section of the main reduction gear cover should be removed by means of chain falls and wire slings. (Larger ships have individual bearing caps for the two intermediate-speed pinion bearings.) Before any bearing cap is disturbed, the propeller shaft must be locked rigidly.

Precautions should be taken not to disturb the location of the intermediate-speed pinion and gear assembly. The shaft should not be lifted or jacked so that the gear teeth become unmeshed. If this is done or if the intermediate-speed group of gears is removed, it will become necessary to follow a detailed and complicated method in order to reassemble and time the gears. The setting up of the locked train gear system is done at the factory and at naval shipyards.

After the bearing cap has been removed, the defective bearing can be moved into position by means of the bearing strap wrench. The upper half of the bearing is removed and inspected. The lower half of the bearing is rolled out, with the aid of a dummy bearing. The dummy bearings are semiannular steel blocks carefully machined to properly support the rotating elements when the journal bearings are out. Dummy bearings to be rolled under the journals should be clean and well oiled. The dummy bearing is rolled in place at the same time that the lower bearing is removed.

The journal surface of the shaft should be carefully inspected and cleaned as often as necessary. The spare bearing should also be cleaned and inspected. The crown thickness, as measured at the factory, is stamped on the spare bearing. For entry purposes, these measurements should be copied on the Machinery History Card. The measurements of the spare bearing should be compared with those of the original

bearing and with the specifications found in the manufacturer's instruction book.

The spare bearing should also be well oiled. The lower half of the bearing can be rolled into place and the dummy bearing removed. The upper half is placed in position and the complete bearing is shifted into its regular position by means of the strap wrench. Care should be taken to see that the bearing and its key are in the required position, in accordance with the manufacturer's instructions. The bearing cap, or assembly, can then be lowered into position and securely bolted down.

The other shaft bearings must also be taken into consideration. The other bearing for the pinion, as shown in figure 3–7, may be damaged as a result of excessive wear. If the end bearing fails, that end of the shaft assembly will raise up and away from the bull gear and an abnormal load will be placed on the adjacent bearing. The other pinion bearing should be opened and inspected. The bearing should be checked with a micrometer, using the crown thickness method. The readings should be compared with the original readings listed on the Machinery History Card and the amount of tolerance allowed, in accordance with manufacturers' instructions. If excessive wear is indicated, the bearing should be replaced with a spare. If time and conditions permit, the other bearings for the shaft assembly should be inspected and measured.

In determining the condition of the other bearing, a great deal depends upon the type of casualty that has occurred. If there is a loss of lubricating oil, the high-speed pinion bearings are first checked. If these bearings are in good condition, it is possible that the other reduction gear bearings are not damaged. However, after the casualty has been corrected, a close watch should be maintained on all bearings.

When the reduction gear is opened, every precaution should be taken to keep out dirt and other foreign matter. The repair personnel should remove all loose articles from their clothing. Foreign particles can be removed from the bull gear case with a hard-woven line wrapped in a bed

sheet. The line is placed around the bull gear in a horizontal position, between the gear and oil pan. With a man holding each end of the line, start the turning gear and roll the bull gear until the line passes completely around from one side of the pan to the other. Repeat this operation in the opposite direction. During this sweeping operation, care should be taken to see that the gears have sufficient lubrication and that no foreign material is forced in between the bull gear teeth. Before the reduction gear is closed, a careful inspection should be made to see that the inside of the gear is free of all dirt, foreign matter, and tools.

### Gear Teeth

Wear-In of Gears. Gears which have been realigned, or new gears, should be given a wearing-in run at low power before being subjected to the maximum tooth pressure of full power.

Tooth Contact. For proper operation of the gears, it is essential that the total tooth pressure be uniformly distributed over the total area of the tooth faces. This is accomplished by accurate alignment, and adherence to the designed clearances.

The designed center-to-center distance of the axes of the rotating elements should be maintained as accurately as practicable, but in all cases the axes of pinions and gear shafts must be parallel. If the shafts are not parallel, the load is concentrated on one end of a helix; the result may be flaking, galling, pitting, feather edges on teeth, deformation of tooth contour, or breakage of tooth ends.

Tooth Contour. The designed tooth contour must be maintained. Teeth are designed for a rolling contact, and if the contour is destroyed a rubbing contact, with consequent danger of abrasion, takes place.

Backlash. This is the play between the surfaces of the teeth in mesh on the pitch circle. Backlash increases with wear, but can increase considerably without causing trouble.

Tooth Surface Wear. If proper tooth contact is obtained when the gears are installed, the initial wearing which takes

place under conditions of normal load and adequate lubrication will smooth out roughnesses and inequalities, and will result in a polished condition of the teeth. As long as operating conditions remain normal, no further wear will occur. This initial wear is referred to as NORMAL WEAR OR RUNNING-IN.

Small, shallow pits, about the size of a pinhead or even smaller, and starting near the pitch line, will frequently form during the initial stage of operation. This is known as INITIAL PITTING; in many cases the pits can be seen only under a magnifying glass. These pits are not detrimental, and usually disappear in the course of normal wear.

Pitting which is progressive and continues at an increasing rate is known as DESTRUCTIVE PITTING. The pits are fairly large and are relatively deep. Destructive pitting is not likely to occur under proper operating conditions, but could be caused by excessive loading, too soft material, or improper lubrication. Since gears for turbine drives are well designed and manufactured to high standards, it will usually be found that when this type of pitting occurs it is due to misalignment or to improper lubrication.

The condition in which groups of scratches appear on the teeth normal to the pitch line—that is, from bottom to top of the tooth—is termed ABRASION, or SCRATCHING. It may be caused by inadequate lubrication, or by the pressure of foreign matter in the lubricating oil. When abrasion or scratching is noted, the lubricating system and the gear spray fixtures should immediately be examined. If it is found that dirty oil is responsible, the system must be thoroughly cleaned and the whole charge of oil centrifuged.

The term SCORING denotes a general roughening of the whole tooth surface. Scoring marks are deeper and more pronounced than scratching and they cover an area of the tooth, instead of occurring haphazardly, as in scratching or abrasion. In some cases, small areas of scoring occur in the same position on all teeth. Scoring usually results from inadequate lubrication, or from inadequate lubrication aggravated by dirty oil. If these conditions are not remedied,

continued operation will result in a general disintegration of the tooth surfaces.

### Root Clearance

The designed root clearance with gear and pinion operating on their designed centers can be obtained from the manufacturer's drawing or blueprint. The actual clearance can be found by taking leads or by inserting a long feeler gage or wedge. The actual clearance should check with the designed clearances; if the root clearance is considerably different at the two ends, the pinion and gear shaft will not be parallel. Provided there is still sufficient backlash, and that the teeth are not meshed so closely that lubrication is adversely affected or that clearance is reduced below specified limits, the tolerance will be satisfactory.

### Alignment of Gear Teeth

When the gear and the pinion are parallel (axes of the two shafts are in the same plane and equidistant from each other), the gear train is aligned. In service the best indication of proper alignment is good tooth contact and quiet operation.

The length of tooth contact across the face of the pinions and gears is the criterion for satisfactory alignment of reduction gears. To check the length of tooth contact, the teeth should be coated with prussian blue, or with copper sulphate, and the gears rolled together with sufficient torque to cause contact between the meshing teeth. After the tooth contact has been determined, the coating should be completely removed to prevent possible contamination of the lubricating oil.

### Spotting Gear Teeth

Any abnormal conditions which may be revealed by operational sounds or by inspections should be rectified with the least practicable delay. Rough gear teeth surfaces should be stoned smooth if it is certain that the roughening was caused

by the passage of some foreign object. . Any deterioration of a tooth surface which cannot be traced directly to a casualty of that nature should be investigated with special attention to the condition of the bearings, to lubrication, and to the possibility of a change in the supporting structure which has disturbed the parallelism of the rotors.

When surfaces of reduction gear teeth are spotted in, the pinion teeth are treated with a light coating of prussian blue (or copper sulfate). The gear is turned in its ahead direction of rotation by means of the jacking gear. As the gear teeth come in contact with the marked pinion teeth, an impression is left on the high part of the gear tooth. After the gear is rotated $\frac{1}{4}$ of a turn, or is in a convenient position for stoning, all the high spots, as indicated by the marking, are removed by a small handstone. It will be necessary to replace the bluing on the pinion teeth repeatedly, but if the bluing is overcoated, false impressions will be left on the gear teeth.

A satisfactory tooth bearing has been obtained when at least 80 percent of the axial length of the working face of each tooth is in contact, distributed over approximately 100 percent of the face width.

Remember that gears should be stoned only to remove a local hump or deformation, but not to remove deep pitting or galling.

### Alignment of Gear and Shafting

Under normal conditions all alignment inspections and checks, with the associated corrective repair work, are accomplished by naval shipyards. Incorrect alignment will be indicated by abnormal vibration, noise, and wear of the main reduction gear. If misalignment is indicated, a complete and detailed inspection should be made by skilled technicians and repair personnel.

MAIN REDUCTION GEAR. Heretofore, block, taper, and telescopic gages have been furnished as a means of checking alignment of the component parts of the main reduction gear against various constants supplied by the manufacturer. These various methods have been replaced by the

Proof Staff Method used by naval shipyards. Detailed information concerning this method may be obtained by referring to chapter 42 of BuShips *Manual*, or to the manufacturer's instruction book.

MAIN PROPELLER SHAFTING. In order to get an accurate check of the propulsion shafting alignment, two sets of measurements should be obtained. One set of readings is taken with the ship in drydock and another set of readings is obtained when the ship is waterborne under a normal loading condition. The main shaft coupling is disconnected and marked. Four measurements are taken each time for each coupling (the top, bottom, and both sides). The main shaft is turned so that a set of readings can be taken with the shaft in four different positions. The condition of alignment of the main shaft can be determined by studying the compiled data of the different measurements taken. The naval shipyard will decide whether or not corrections in alignment are necessary.

TURBINE SHAFTING. The flexible coupling is supported and aligned by two bearings, one at the end of the turbine and another on the gear case. These bearings must be set so as to maintain the most accurate alignment, both as to the centering and the allowance for a small change in position of alignment, while running. Any inaccuracy in setting, as well as poor balance in the coupling itself, will cause pounding and excessive wear of the bearings. If the alignment is affected by temperature, or strain of the gearing, compensating adjustments should be made, or the seating properly braced and strengthened.

In most cases, the manufacturer's instruction book will give information on methods of checking the alignment of the turbine shafting.

## CHECKING THE MAIN THRUST BEARING

This chapter will give you general information on the different methods of taking end play readings for the main thrust bearing. In regard to your own ship, detailed information on allowable tolerances and procedures for taking

thrust bearing readings can be obtained from the manufacturer's instruction book.

End play checking of a 6- or 8-shoe bearing must always be done with the upper half of the housing solidly bolted down, since otherwise the base rings could tilt under the freedom given by the leveling plates, and a false reading would be obtained.

A record of the end play measurements should be kept in the Machinery History and referred to when checking the main thrust bearing. The normal wear of a pivoted shoe-type thrust bearing is negligible even with years of use. However, when new, there may be slight settling of the leveling plates of a 6- or 8-shoe bearing. Any noticeable increase in the end play indicates that the thrust shoe surfaces should be examined, and repairs made if necessary.

In most cases, a port is provided in the main thrust bearing cap over the thrust shoes, for inspection purposes. This port has a removable cover and is of such size that it will permit the withdrawal of the pair of ahead and astern thrust shoes located (by means of the turning gear) in line with it.

## Checking the End Play While Running

The simplest method of checking end play is to use a suitable measuring instrument on any accessible part of the propeller shaft while running the turbine slowly ahead and astern. This would normally be accomplished at the end of a run when the ship is maneuvering to approach her pier, before the machinery and shaft are cold. The speeds should be slow to avoid adding deflections of bearing parts and housing to the actual end play. However, the speeds should be sufficient to overcome the rake of the shaft and to ensure that the full end play is actually taken up. The method of applying this procedure will depend somewhat on the type of bearing, as follows:

MICROMETER AT FORWARD END OF THRUST BEARING. Most ships have the main thrust bearing located at the forward end of the main reduction gear. The main thrust bearing is

actually constructed as a component part of the reduction gear. A spring-loaded pin gage is provided in the thrust bearing end cover housing. A micrometer depth gage is used to measure the end play. The installed pin gage cover is removed. The anvil of the depth gage is placed on the machined surface of the installed pin gage housing. The micrometer is carefully turned so that the spindle pushes the installed pin against the main shaft. All slack must be taken up, but excessive force must not be used, as it will lift the micrometer anvil from the machined surface. Another reading is similarly taken with the main shaft operating in the opposite direction. The difference between the two readings (forward and astern thrusts) is the end play.

INDICATOR ON SHAFT FLANGE OR SHOULDER. On some ships, particularly on turboelectric driven ships, different methods must be used to measure the end play of the main thrust bearing. The end play is measured by means of a dial indicator, mounted on a rigid support close to any convenient coupling flange. Occasionally the shaft may have a shoulder turned on it for the sole purpose of applying a dial indicator. Care must be taken to see that a flange surface is free from paint, burrs, and rust spots. The flange surface should also be well oiled in order to prevent damage to the dial indicator.

### Jacking on Shaft Flange

If it is not feasible to measure the end play while running, the next choice is to jack the shaft fore and aft at some convenient main shaft flange.

A dial indicator, or a micrometer depth gage, may be used as explained in the preceding paragraphs. Make certain that the shaft movement is free; guard against overdoing the jacking force, however, to avoid adding the deflections of metal parts to the actual end play. The readings are taken in a manner similar to that previously described. The difficulty regarding the use of the jacking method is finding suitable supports where no structural damage will be incurred in jacking against a main shaft flange coupling.

### Jacking by Means of Thrust End Plate

With a 6- or 8-shoe bearing at the forward end of the reduction gears, the end play may be measured in the thrust bearing itself. A circular adjusting liner or filler piece is enclosed in the housing bore between the end cover plate and the forward base ring. The end cover and filler piece should be removed and a specially made dummy filler, at least ⅛-inch thicker than the regular filler, is substituted. The dummy must be smooth and flat and of uniform thickness, accurately measured and recorded.

With the dummy filler in place of the regular filler, replace the end cover, then tighten the bolts evenly all around, using a hand wrench. Draw up the housing bolts until the thrust collar bears hard on the astern thrust shoes, and the space between the end cover flange and the face of the housing is uniform all around. Using feelers, measure the air gap at several points between the end cover and the housing flange, and equalize the air gap all around, with the cover bolts evenly tightened. From the thickness of the dummy filler subtract both the thickness of the regular filler and the air gap. The remainder is the end play. If the filler piece has been shimmed and the shims have been removed with the filler, the thickness of the shims must naturally be taken into consideration when calculating the end play.

## TESTS AND INSPECTIONS

The tests and inspections mentioned here are the minimum requirements only. Where defects are suspected, or operating conditions so indicate, inspections should be made at more frequent intervals.

To open any inspection plates or other fittings of the main reduction gear, permission should first be obtained from the engineer officer. Before replacement of an inspection plate, connection, fitting, or cover which permits access to the gear casing, a careful inspection must be made to ensure that no foreign matter is present in the casing or oil lines. Inspections should be recorded in the engineering log, with the

name of the CPO or officer who witnessed the closing of the inspection plate.

### Routine Inspections

a. DAILY—AT ANCHOR. Jack gears so that the main gear shaft is moved 1¼ revolutions. This jacking should be done with lubricating oil circulating in the system.

b. QUARTERLY. The following tests and inspections should be made:

(1). Sound with a hammer, holding down bolts, ties, and chocks to detect signs of loosening of casing fastenings.

(2). Open inspection plates, inspect gears and oil-spray nozzles. Wipe off oil at different points and note whether the surface is bright, or if already corroded, whether new areas are affected.

(3). Inspect the strainers for the oil-spray nozzles to see that dirt or sediment has not accumulated therein.

(4). Take and record main thrust bearing readings.

c. EVERY 5 YEARS. When conditions warrant or if trouble is suspected, a work request may be submitted to a naval shipyard to perform a 5-year inspection of the main reduction gears. This inspection includes clearance readings of bearings and journals; alignment checks and readings; and any other inspections, tests, or maintenance work that may be considered necessary.

d. WHEN OCCURRING. If the ship's propeller strikes ground or a submerged object, a careful inspection should be made of the main reduction gear. In this inspection, the possible misalignment of the bull gear and its shaft should be taken into consideration. Where practicable, a naval shipyard should be requested to check the alignment and concentricity of the bull gear.

### Naval Shipyard Overhaul

Inspect condition and clearance of thrust shoes to ensure proper position of gears. Inspect thrust collar, nut, and locking device. Inspect flexible couplings between turbines

and reduction gears; remove sludge deposits and, if necessary, stone the surfaces.

### Full Power Trials

The correction of any defects disclosed by regular tests and inspections, and the conscientious observance of the manufacturers' instructions, should assure that the gears are ready for full power at all times.

BEFORE TRIALS. In addition to inspections which may be directed by proper authority, open the inspection plates, examine the tooth contact, the condition of the teeth, and the operation of the oil-spray nozzles. It is not advisable to open gear cases, bearings, and thrusts immediately BEFORE TRIALS.

AFTER TRIALS. In addition to the inspections which may be directed by proper authority, open the inspection plates, and examine the tooth contact and the condition of the teeth to note changes that must have occurred during the trials. Running for a few hours at high power will show any possible condition of improper contact or abnormal wear that would not have shown up in months of operation at lower powers.

Check the clearance of the main thrust bearing.

## SAFETY PRECAUTIONS

1. If there is churning or emulsification of the oil in the gear case, the gear must be slowed down or stopped until the defect is remedied.

2. If the supply of lubricating oil to the gears fails, the gears should be stopped until the cause can be located and remedied.

3. When bearings are overheated, gears should not be operated, except in extreme emergencies, until bearings have been examined and defects remedied.

4. If excessive flaking of metal from the gear teeth occurs, the gears should not be adjusted, except in case of emergency, until the cause has been determined.

5. Unusual noises should be investigated at once, and the

gears should be operated cautiously until the cause for the noise has been discovered and remedied.

6. No inspection plate, connection, fitting, or cover which permits access to the gear casing should be removed without specific authority of the engineer officer.

7. The immediate vicinity of an inspection plate joint should be kept free from paint and dirt.

8. When gear cases are open, precautions should be taken to prevent the entry of foreign matter. The openings should never be left unattended unless satisfactory temporary closures have been installed.

9. Lifting devices should be inspected carefully before being used and should not be overloaded.

10. Naked lights should be kept away from vents while gears are in use (the oil vapor may be explosive).

11. When ships are anchored in localities where there are strong currents or tides, precautions should be taken to lock the main shafts.

12. Where the rotation of the propeller may result in injury to a diver over the side, or in damage to the equipment, propeller shafts should be locked.

13. When a vessel is being towed, the propellers should be locked, unless it is permissible and advantageous to allow the shafts to trail with the movement of the ships.

14. In case a shaft is allowed to turn or trail, the lubrication system must be in operation. In addition, a careful watch should be kept on the temperature within the low-pressure casing of the turbines to see that windage temperatures cannot be built up to a dangerous degree. This can be controlled either by the speed of the ship or by the vacuum maintained in the main condenser.

15. The main propeller shaft must be brought to a dead stop position before the clutch of the turning gear is engaged. (If the connecting shaft to the high-speed pinion of the high-pressure turbine is revolving at considerable speed, the jacking gear will be damaged.)

16. When locking a main shaft, precautions must be taken to quickly and securely apply the brake to the jacking gear. (If there is a delay in applying the brake or if the brake is not secured properly, the jacking gear may begin to rotate with the main propeller shaft. If this occurs, the jacking gear will be damaged because of excessive speed. Reduction ratios as high as 16,000 to 1, between the propeller shaft and the turning gear motor, are used.)

17. When a main shaft is to be unlocked, precautions must be taken to disengage the jacking gear clutch before releasing the brake. (If the brake is released first, the jacking gear may begin to rotate with the main shaft. This may result in damage to the jacking gear as well as injury to personnel.)

18. In an emergency, where the ship is steaming at a high speed, the main propeller shaft can be stopped and held stationary by the astern turbine until the ship has slowed down to a speed where the main shaft can be safely locked.

19. Where there is a limiting maximum safe speed at which a ship can steam with a locked propeller shaft, this speed should be known and not exceeded.

20. When the main turbines are to be jacked, a check should be made to see that the turning gear is properly lubricated. (Many ships have a valve in the oil supply line leading to the turning gear. The operator should see that this valve is open before attempting to put the turning gear in service.)

21. It should be definitely determined that the turning gear has been disengaged before the main engines are started.

## SUMMARY

The efficient lubrication of reduction gears is of utmost importance. Inspections of the reduction gears will readily indicate whether or not pure lubricating oil has been used. Conditions such as dirty oil, water in the oil, or condensation will cause rust to appear on the gears and pinions. Rust-

ing and pitting of gears can be prevented by jacking 1¼ turns daily and covering the gears with oil when they are not in use.

Particular care must be taken to clean out metal flakes and fine chipping when new gears are wearing into a working fit. Routine checks should be made to see that the lubricating oil is maintained at the proper level in the sump. Any sudden loss or gain in the amount of oil should be immediately investigated.

Some of the principal causes of tooth wear are foreign material, worn bearings, misalignment, excessive shaft deflection, and undue vibration. These conditions result in various types of tooth surface wear.

A record of the end play measurements of the main thrust bearing should be kept on the Bearing Record Card in the Machinery History and referred to when each check is made. Any noticeable increase in the end play indicates that the thrust shoe surfaces should be examined by means of the inspection opening.

## QUIZ

1. What type of main reduction gearing is used on steam-driven destroyer escorts and on some naval auxiliary ships?
2. What type reduction gear is the simplest of all double reduction helical gearing?
3. What type of reduction gear is used on most naval combatant ships?
4. Who may authorize the alteration of oil-spray apparatus in a main reduction gear?
5. Where should samples of lubricating oil be tested for acid, water, and sediment content?
6. If there is too much oil in the sump and the gear churns and aerates the oil, how is the temperature affected?
7. If the propeller shaft is in locked position for more than 5 minutes, what is likely to occur?
8. When is an unusual noise on multishaft turbine-geared vessels likely to occur?
9. What should be done if the main reduction gear vibrates?
10. The vibration of the main reduction gears may result from what three causes?



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11. In cases where the ship has been damaged, what is likely to cause the main reduction gear to vibrate?
12. Under normal conditions, all repairs and major items of maintenance work on main reduction gears should be accomplished by which personnel?
13. In the event that a main reduction gear bearing, on a multishaft ship, becomes wiped, what is the preferred procedure to take, if practicable?
14. In case of a low lubricating oil casualty, which group of bearings are checked first?
15. Why must a careful inspection of the reduction gear be made before closing the gear?
16. Destructive pitting generally results from what causes?
17. What will be indicated by a root clearance which varies considerably at the two ends of the gear?
18. What is the criterion for satisfactory alignment of reduction gears?
19. When spotting in surfaces of reduction gear teeth, what is used to coat the pinion teeth?
20. In order to obtain a satisfactory tooth bearing, a minimum of what percent of the axial length of the working face of each gear tooth must be in contact?
21. When is the stoning of gears most useful?
22. How many sets of measurements should be obtained to get an accurate check of the propulsion shafting alignment?
23. Why must end play checking of a 6- or 8-shoe bearing be accomplished with the upper half of the housing bolted down solidly?
24. What should be done if there is a noticeable increase in the end play of a main thrust bearing?
25. What is the simplest way to check the end play of the main thrust bearing?
26. What instrument is used to measure the end play of a main thrust bearing located at the forward end of the main reduction gear?
27. How frequently should the main thrust bearing clearances be taken?
28. If the supply of lubricating oil to the gears fails, what procedure should be taken?
29. Aboard ship, who authorizes the removal of an inspection plate, connection, fitting, or cover?

# CHAPTER 4

## CONDENSERS AND HEAT EXCHANGERS

This chapter deals with the care and maintenance of condensers, air ejectors, and lubricating oil coolers, and with the operation of deaerating feed tanks.

### CONDENSATE DEPRESSION

Compared with the amount of steam discharged into the condensers, the capacity of the air removal equipment is small. Therefore, the condenser is arranged so that the air is separated from the steam, insofar as practicable, in order that the air ejector will not be overloaded by having to pump large quantities of steam, with the air, out of the condenser. Therefore, most condensers are furnished with air-cooling sections separated from the remainder of the condensing surface by air baffles. An example of this arrangement is shown in figure 4–1.

By referring to figure 4–1, you will notice that the central steam lane extends completely through the tube bundle and provides for the passage of steam from the exhaust inlet directly to the condenser hot well. The steam reaching the hot well reheats the condensate, which has been cooled by physical contact with the cold tube surfaces. As the steam passes through the condenser, it expands outward towards the sides of the condenser shell. This flow of steam tends to sweep the air which would otherwise collect in the hot well up to the air cooling section and air baffles. (The temperature of the condensate should be maintained as high as possible.)

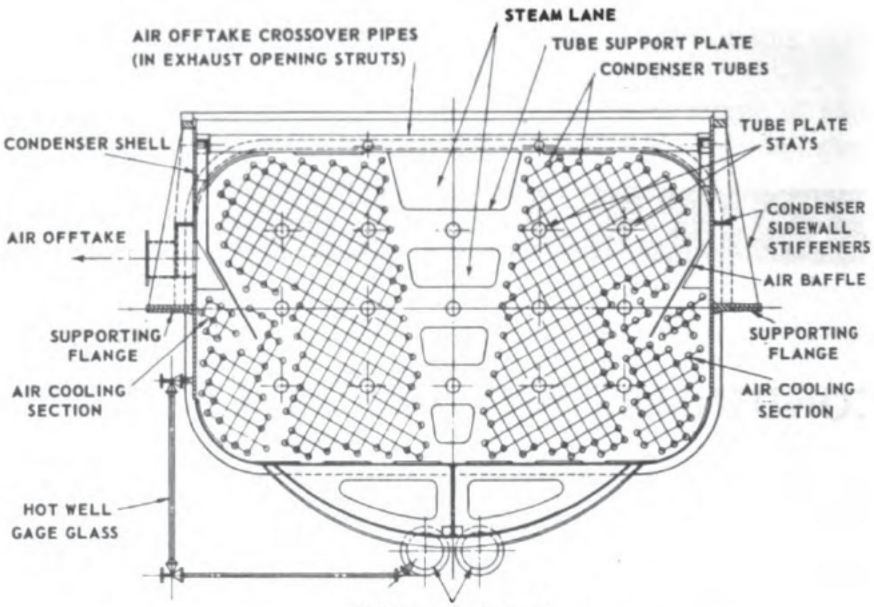


**Figure 4–1.—Cross-sectional view of a typical condenser.**

The steam reaching the hot well reheats the condensate to a temperature corresponding to the vacuum maintained in the hot well. The difference between the temperature of the condensate discharge and the temperature corresponding to the vacuum maintained (shown in the table) at the exhaust inlet to the condenser is referred to as "condensate depression."

The following table shows the pressure-temperature relationship in the range normally dealt with in shipboard condenser operation:

| *Absolute pressure, inches of mercury* | *Temperature of condensate discharge, °F* | *Corresponding vacuum, 30-in. barometer* | *Absolute pressure, inches of mercury* | *Temperature of condensate discharge, °F* | *Corresponding vacuum, 30-in. barometer* |
|---|---|---|---|---|---|
| 0. 4 | 52. 6 | 29. 6 | 2. 2 | 104. 6 | 27. 8 |
| . 6 | 64. 0 | 29. 4 | 2. 4 | 107. 3 | 27. 6 |
| . 8 | 72. 3 | 29. 2 | 2. 6 | 110. 1 | 27. 4 |
| 1. 0 | 79. 0 | 29. 0 | 2. 8 | 112. 6 | 27. 2 |
| 1. 2 | 84. 6 | 28. 8 | 3. 0 | 115. 1 | 27. 0 |
| 1. 4 | 89. 5 | 28. 6 | 3. 5 | 120. 6 | 26. 5 |
| 1. 6 | 93. 8 | 28. 4 | 4. 0 | 125. 4 | 26. 0 |
| 1. 8 | 97. 6 | 28. 2 | 4. 5 | 129. 8 | 25. 6 |
| 2. 0 | 101. 1 | 28. 0 | 5. 0 | 133. 8 | 25. 0 |

A very high condensate depression (a large difference between the two temperatures) decreases the operating efficiency of the plant, since the subcooled condensate must be reheated by the deaerating feed tank. This requires the expenditure of more steam for feed heating than would otherwise be necessary. Excessive condensate depression prevents the condenser from properly deaerating the drains and the make-up feed discharged to it. This results in an accumulation of air, which puts an additional load on the deaerating feed tank.

Under steady operating conditions, an abnormally high condensate depression indicates excessive air leakage, excessive flow of circulating water, or improper functioning of air removal equipment. It is normal for an increase in condensate depression to occur when make-up feed is admitted into the condenser. With the make-up feed line secured, the average condenser aboard naval ships should, under proper operating conditions at low and medium powers, maintain a condensate depression of 0 to 2°.

Under high power operating conditions, it is normal to expect a high condensate depression. This is caused, particularly under cold injection temperature conditions, by the overloading of the steam passages leading to the hot well and by increases in the pressure drop of the steam traversing the condensing surface. The net result is a greater vacuum in the hot well than in the condenser exhaust trunk. Thus, the condensate is cooled to a temperature corresponding to a higher vacuum (hot-well vacuum) than the vacuum maintained in the exhaust trunk, and there is an apparent increase in condensate depression.

Accurate condensate depression determinations of a particular condenser installation, and a knowledge of the condensate depression to be normally expected under various operating conditions, are of great value in determining whether the condenser is operating properly and whether adjustments and corrective measures are required. As the temperature differences involved are usually small, it is essential that thermometers installed in the condensate line be

maintained in satisfactory condition and that exhaust trunk temperatures or vacuum be measured accurately.

### Vacuum Regulation

Under normal operating conditions, condensers fitted for scoop injection should be operated to maintain the maximum vacuum obtainable, with the main injection and overboard valves wide open, except under the following conditions:

FULL POWER. When making full power, or speeds closely approaching full power, under cold injection temperature conditions, the condenser will usually be capable of maintaining a higher vacuum than can be effectively used by the low-pressure turbine. In the average installation, as the full power vacuum becomes higher than about one inch of Hg above that for which the low-pressure turbine was designed, the extra steam required for heating the condensate tends to outweigh the added economy of turbine installation. The designed full power vacuum for any turbine installation may be obtained from the manufacturer's instruction book. Most turbines served by scoop injected condensers are designed for an exhaust vacuum of about 27½ inches Hg (1¼ psi absolute). If the injection temperature becomes low enough so that the full power vacuum tends to increase above 28½ inches Hg, improved over-all plant economy may be obtained by throttling the flow of circulating water to limit the vacuum to 28½ inches Hg.

CRUISING SPEEDS. When operating at cruising speeds, the turbines can generally make effective use of the maximum vacuum which the condensing plant is capable of maintaining. However, with cold injection at low power, the condenser becomes capable of producing a vacuum higher than that produced during normal operating conditions. Under standby conditions and with very little steam discharged to the condenser, most installations fitted with properly functioning air ejectors will produce a maximum vacuum of approximately 29½ inches Hg, with cold injection temperature.

As the condenser vacuum approaches the maximum under standby conditions, and with cold injection temperature, the

air removal equipment tends to become unable to free the condenser of normal air leakage. The air collects in the condenser, tends to insulate the tubes from the condensing steam and settle into the hot well, and there is usually a noticeable increase in the condensate depression. To avoid loss of economy and absorption of air into the condensate under these conditions, it is good practice to throttle the flow of circulating water, as necessary, to limit the vacuum to about 0.2 inch Hg less than the maximum obtainable with full flow of circulating water, or as necessary to reduce the condensate depression to normal. Under low power operation at medium injection temperature, if the condensate depression remains between 0 and 2°, it may be assumed that the air removal equipment is ridding the condenser of air leakage, and throttling of circulating water is unnecessary.

### Circulating Water Regulation

When the gate valves in the circulating water discharge piping are used to regulate water flow through the condensers, these valves should be kept at least ¼ open. If a gate valve used for throttling service is closed more than ¾, the disk is likely to pound against the valve seat and damage the valve so that it will not be watertight when closed. Some limited erosion of the gate valve disk and seating surfaces may be experienced in cases where overboard gate valves are continually used for throttling. Careful inspection should be made whenever the ship is drydocked, in order that the seating surfaces may be kept in proper condition.

If, while an overboard valve is set for throttling, a sudden increase in power needed, some further opening of the valve will generally be required; however, the temporary loss in vacuum to be expected before readjustment has been effected is usually not large or serious. In the event of an unexpected demand for full power astern, the overboard valve should be opened wide as quickly as possible.

## CONDENSER TUBE DETERIORATION

Most tube failures can be traced to either galvanic corrosion or impingement erosion.

## Galvanic Corrosion

If dissimilar metals, immersed in an electrolyte (such as salt water), are connected, a simple galvanic cell is formed and an electric current flows from one metal to the other through the electrolyte. The metal from which the current is flowing to the electrolyte will tend to corrode rapidly (galvanic or electrolytic corrosion), and the metal to which the current is flowing from the electrolyte will tend to be protected from galvanic corrosion. The direction in which the current will flow depends upon the composition of the metal or the alloys exposed to the electrolyte. If several metals or alloys are involved, current will flow in varying proportions between the surfaces exposed to the electrolyte.

Since condensers and heat exchangers using salt water have all the requirements of a simple galvanic cell, electrolytic action will take place. This action cannot be stopped; however, the metal parts of condensers and heat exchangers may be protected by the use of zinc plates. Because of its characteristics, zinc metal will cause the electric current to flow from the zinc plates to the other metallic parts of a condenser. The effect of the electrolytic action will be to gradually destroy the zinc plates, but they can readily be replaced.

The drawings for any condenser or heat exchanger will show the number and specific sizes of the zinc pieces provided in its design. In general, a zinc piece should be replaced when it is 50 percent or more deteriorated.

Specific information concerning the attachment of zinc protector plates and the maintenance of zincs is given in chapter 46 of BuShips *Manual*.

## Impingement Erosion

Sea water flowing into condenser tubes at a high velocity tends to remove the thin protective film of corrosion products adhering to the base metal of the tube wall. This protective film is replaced at the expense of further corrosion of the

tube wall. As continued removal and replacement of the protective film of corrosion proceeds, the tube wall is gradually thinned, the joint between the tube and the tube sheet is weakened, and a sea-water leak ultimately occurs through failure of the joint, or perforation of the tube wall beyond the tube sheet. This type of attack is generally confined to the region of the tube at or near the inlet end and is known as impingement erosion, inlet end attack, air erosion, or bubble attack. The occurrence and rapidity of the attack is influenced mainly by water velocity through the tubes. It is also influenced by the amount of air entrained with the circulating water, and by the design of water chests and injection piping.

Tube deterioration resulting from impingement erosion of the tube ends can be minimized by proper regulation of circulating water through condensers and heat exchangers, and a safe maximum operating temperature in the case of heat exchangers, together with proper venting of the water chests. Whenever water chest manhole or handhole covers are removed for cleaning condensers or inspecting zincs, inlet tube ends should be examined.

Figure 4–2 shows a tube which has been badly damaged at the inlet end by impingement erosion.

**Figure 4–2.—Tube damaged by impingement erosion.**

Baffles or distribution pipes are installed within the condenser shell to prevent direct impingement of the auxiliary exhaust dumping line, the recirculating line, the make-up

feed line, etc., against the tubes. These baffles should be inspected for condition and security whenever access to the condenser is provided for any purpose and whenever it is suspected that a steam side baffle has carried away or become perforated. Baffles should not touch the tubes, as vibration may cause failure of tubes. Frequent tube leaks in the vicinity of a steam or water connection to the condenser shell offer almost positive evidence that the baffling system is defective or that the plant is operating improperly.

In order to prevent tube erosion from an auxiliary exhaust dumping line, it is essential that the line be thoroughly and continuously drained at all low points. If any undrained pocket exists where condensate can collect in the line ahead of the back-pressure valve, it should be requested that a drain well be installed and connected via an automatic trap to the fresh water drain collecting system, in such a manner as to secure positive and complete drainage under all operating conditions. Unless the auxiliary exhaust dumping line to a condenser is thoroughly and continuously drained, rapid tube erosion can be expected.

In general, it is unnecessary to install baffles in the way of the main steam inlet to condensers serving turbines, as the steam is not wet enough nor the velocity high enough to cause tube erosion.

## MAINTENANCE OF MAIN AND AUXILIARY CONDENSERS

### Idle Condensers

Most condensers and tubular heat exchangers on naval ships have condenser tubes either expanded at both ends, or expanded at the inlet end and packed with fiber-metallic packing (symbol 1435) at the outlet end. These units should normally be kept empty and drained when secured. However, if the condensers are to be used within a few days, they may be completely filled with water, which should be circulated daily unless the ship is lying in highly polluted waters. When in polluted harbors, the condensers should be drained and thoroughly washed out whenever secured.

Whenever the sea-water side of a condenser is drained, special care should be taken to ensure that the tubes do not have water anywhere along their individual lengths. Individual tubes frequently become sagged. Water trapped in these pockets at one or more points along the tube length, if allowed to remain in a drained condenser, will gradually evaporate. The impurities left behind will corrode the tube at these points and in time result in tube failure. The action is particularly acute when condensers are drained of the highly polluted water. The best method of avoiding this type of tube deterioration, when an ample supply of fresh water is available from a dock or pier, is to water-lance each tube with fresh water in order to wash out the polluted water and remove foreign matter from the tubes. Following the water-lancing operation, the tubes should be air-lanced and left dry until the condenser is again put in service.

If sufficient fresh water is not available for water-lancing, each condenser tube should be air-lanced and left completely dry. In this case, the condenser should be inspected daily. If any water tends to collect in the tubes, through condensation from the atmosphere, the air-lancing operation should be repeated, as necessary, to avoid the formation of water pockets at low points along the tubes.

When a condenser is secured, the steam side should be emptied and kept drained.

## Inspection of Condensers

Under normal operating conditions, the salt-water side of the condenser should be inspected once each month or immediately after an extended cruise. The steam side of the condenser should be inspected each quarter when the inspection covers are removed from the low-pressure turbine.

When the ship is under way, conditions may arise which will necessitate additional inspections of condensers. At times a ship may operate in very shallow water, or may operate in waters where there is a large amount of seaweed, schools of small fish, or large amounts of oil. When the

above conditions occur, the condenser should be inspected and cleaned as necessary.

A noise inside the inlet header of the condenser may indicate a loose zinc plate, or a foreign object inside the header. The condenser should be secured as soon as practicable in order that damage to the tubes and tube sheet may be prevented. If a loose zinc plate, or any foreign object is found, it is possible that some of the tube ends have been damaged and it will be advisable to test the condenser.

## Cleaning of Condensers

Foreign matter lodged on the sea-water side of the condenser tubes interferes with and reduces the flow of sea water, thereby retarding the heat transfer from the condensing steam to the circulating water. This, in turn, reduces the maximum vacuum obtainable, and lowers the efficiency of the condenser. Frequent visual inspections provide the only safe means of knowing if condenser fouling exists.

Cleaning Watersides. For ordinary cleaning, an air lance should be pushed through each tube, tube sheets washed clean, and all foreign matter removed from the water chests. In cases of severe fouling, a water lance should be pushed through each tube to remove foreign matter adhering strongly to the interior. The condenser tubes are made of corrosion-resistant material. The resistance depends upon the formation of a microscopically thin, continuous film of corrosion products which adheres to the surface of the tubes. The film is itself resistant to further corrosion, and as long as it remains intact, it protects the tube from corrosive action. A break in the protective coating can be repaired only at the expense of the tube metal as it combines with the corrosive elements of the sea water. If the cause is not removed, corrosion of the tube will continue and lead to the formation of a corrosion pit, and eventually to tube failure.

Boiling Out. Foreign matter on the steam side of a condenser may be removed by boiling out with a strong solution of Navy standard boiler compound. Under normal condi-

tions, condensers should not require boiling out more frequently than every 2 or 3 years. When a ship is placed back into commission from a reserve fleet, condensers should be boiled out to remove preservative material.

To boil out a condenser, proceed as follows:

1. Drain and clean the sea-water side.

2. Close all valves in lines connected to the condenser.

3. Mix 200 gallons of fresh water with 100 pounds of boiler compound, for each 1000 gallons of water the steam side of the condenser will hold, and dissolve the compound in hot water. Introduce the mixture into the condenser shell.

4. Fill the steam side of the condenser with fresh water to above the top row of tubes. At boiling temperature, care should be taken to prevent any water from entering the low-pressure turbine.

5. Through the boiling-out connection, introduce live steam into the condenser and bring the contents to the boiling point at atmospheric pressure. During this operation, the condenser should be vented to the atmosphere. This can best be accomplished by removing both a forward and after manhole plate from the low-pressure turbine casing and installing portable blowers.

6. Boil the solution for about 12 hours, at the same boiling point obtained in the previous step. (Sufficient steam must be continuously introduced to assure that boiling of the solution is maintained. Vibration and noise resulting from live steam entering the condenser shell does not necessarily indicate that boiling of the solution is taking place.)

7. Drain the condenser to the bilges or, preferably, pump the solution overboard if convenient means are available. See that no emulsion enters the feed system.

8. Wash out the condenser several times with a fresh-water hose. Be sure to wash out any sediment collected in the bottom of the hot well.

9. Test the condenser for leaks.

10. Before and during this boiling out of a condenser, the officer and the CPO in charge should inspect all boiling out

and draining arrangements to guard against accidents, and see that proper safeguards are provided for the men engaged in this work.

### Tube Leaks

It is not unusual for a newly tubed condenser, during the first few months of its operation, to develop leaks resulting from a few initially defective tubes, or tube joints. However, if the unit is properly cared for in service, it may give excellent service for years.

The most common cause of tube leaks is deterioration which starts at the sea-water side and proceeds through the tube wall to the steam side. Leakage may also be caused by deterioration starting at the steam side of the tube wall, by a defective joint between the tube sheet and the tube, or by cracking of the tube wall or the tube sheet.

TESTING THE CONDENSER FOR LEAKS. Careful planning is necessary if a condenser must be tested for leaks while the ship is at sea. The work should be well coordinated and expedited, so that the main plant will remain out of commission for the shortest possible period. The testing and repair work should be carefully performed; otherwise the work will have to be repeated. Safety precautions should be observed in working with the sea-water side of the main condenser in order to prevent water from overflowing into the engineroom.

To check for small or large leaks, drain the seawater side and fill the steam side of the condenser with fresh water to as high a level as possible. Remove the water chest inspection plates. With turbine installations, put approximately 5 psi sealing steam on the glands, close all valves through which air can escape from the turbines, and isolate the low-pressure turbine as much as possible from the preceding turbine. If the installation is a small one, the exhaust opening into the condenser may be blank-flanged. Cover all the tube ends with a heavy coating of soapsuds. Apply an air pressure of approximately 5 psi on top of the water. To

obtain this pressure in a condenser, it will generally be necessary to operate the ship's service air compressing plant at capacity. If the exhaust opening is not blank-flanged, a large amount of air will escape. Leaks will be indicated either by trickling of water or by air bubbles.

PLUGGING DEFECTIVE TUBES. Tubes which fail during the operation of a condenser should be plugged at each end by using the metal or phenolic tube plugs furnished with the repair parts. Plugs should be driven firmly into the ends, using light hammer blows. Care should be taken not to break the plugs by hitting them off center.

In general, 5 to 10 percent of the total number of tubes can be plugged without seriously affecting the operation of the condenser. Tube failures in excess of 10 percent necessitate the complete or partial retubing of a condenser.

If it becomes necessary to plug tube sheet holes after a tube has been removed, it is good practice to install short sections of a tube in the tube holes and secure them, by expanding, prior to inserting the tube plugs (in order to protect the tube sheet from damage). Plugged tubes should be renewed at the first shipyard or tender availability of the ship, if water chests are removed for other work. Care must be taken that tubes which are leaking at the tube joints, but are otherwise in good condition, are not plugged. In such cases, the proper repair involves rerolling or repacking the tube joint, as appropriate.

If several tube leaks occur in the vicinity of a steam or water inlet to the condenser shell, erosion should be suspected. To determine the probable cause of erosion, the manufacturer's instruction book should be studied carefully. If practicable, the baffle arrangement should be inspected for material conditions and installation, in accordance with the blueprints. Replacement of a defective baffle plate, or a change in the operating procedures, may be all that is necessary to correct the trouble. If no satisfactory correction can be made, detailed information on the unsatisfactory condition should be given to BuShips.

In some cases, a condenser tube sheet may have a porous area or crack. In general, porous or cracked tube sheets cannot be permanently repaired. However, porosity can be temporarily corrected by tinning or by peening. A tube sheet crack should be stitched with threaded copper or brass plugs. The plugs are placed close together in the crack and the ends of the plugs are riveted down lightly but thoroughly. It is generally necessary to withdraw a number of tubes at the ends of the crack and permanently close these tube holes with special threaded plugs. If possible, a porous or cracked tube sheet should be repaired by a shipyard. Any indication of a porous or cracked tube sheet should be reported to BuShips so that arrangements for permanent repairs can be made.

## RETUBING OF CONDENSERS

Under normal conditions, an MM1 or C will not be expected to retube a condenser. Because of modern materials and manufacturing methods, condensers seldom require retubing. When they do, special tools and equipment are necessary, and the work is performed by tenders or by a naval shipyard. However, the MM1 or C has the responsibility of inspecting the job, to see that it has been properly completed and tested, and that the workmanship is according to the best standards.

### Inspection of Specimen Tubes

In general, specimen tubes should not be drawn from a condenser or heat exchanger, for examination purposes, except when specifically directed by BuShips, or by a Board of Inspection and Survey. Under the following conditions, however, tubes may be drawn without BuShips authorization:

1. When frequent leaks have been caused by tube failures, specimen tubes should be drawn from widely separated parts of the unit in order to establish the general condition of tubes.

2. When several tubes have failed in the vicinity of a steam or water inlet to the condenser shell, specimen tubes

should be drawn unless the cause of the failure can be determined by visual inspection of the steam side of the unit.

Samples from the most badly deteriorated tubes should be carefully marked to show the top and the bottom of each sample, and the location from which the sample was drawn. The samples should be cut in lengths of about 12 inches, identified as to position along the length of the tube, split lengthwise and opened out to permit ready examination. These samples are then forwarded to BuShips, together with a complete report of the conditions found.

In order that the required data may be readily available, a Machinery History Card should be kept for each condenser.

### Retubing Request

Before any work is begun in retubing a main condenser, authorization must be obtained from BuShips. The following information must accompany any retubing request:

1. A complete report of the conditions found, definitely stating:

a. The condenser involved and the date when the condenser was last tubed or retubed

b. Whether or not any of the tube leaks were caused by improperly expanded or packed tube joints

c. The date when each leak occurred, the type of tube failure (usually determined when the failed tube is drawn and split for inspection), the conditions of operation, and any known or suspected contributory causes.

d. The source of supply of the tube, if known

e. The position in the tube bundle of each failed tube and of each specimen tube drawn for inspection

f. The part(s) of each specimen tube where defects were found (external, internal, top, bottom, sides, ends, etc.); to meet these requirements, tube ends must be marked before removal so that the top can be located

g. The tube, tube sheet, water box material, and the type of tube joints employed



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h. The conditions of zincs, the frequency of renewal of zincs, the frequency of scaling operations, and the method of scaling

i. The method of cleaning tubes and frequency of cleaning operations

j. Whether or not the unit was kept thoroughly vented during its operation

k. Whether or not the tubes were cleaned and blown out whenever sea water was drained from the unit

l. What other corrective measures have been applied

2. If severe deterioration of tube ends and of tube sheets is visible and photographic equipment available, photographs of the tube sheets should be taken and forwarded to BuShips for information

3. The extent of work considered necessary (partial retubing is not considered normally economical, except that authority is sometimes given for retubing one pass of a 2-pass unit)

4. A list of materials required, specifying length, outside diameter, wall thickness, and type of tube joints at both inlet and outlet ends

5. Recommendation and comment by superior authority endorsing the request

Subject to approval by the type commander, retubing of auxiliary condensers or of other type of heat exchangers may be undertaken by forces afloat or by a naval shipyard when necessary, without obtaining authority, in advance, from BuShips.

Complete reports of any such retubing should be forwarded to BuShips and include the information required, as outlined above, for main condensers.

### Removal of Tubes

When a condenser is to be retubed, the old tube may be rapidly removed by special equipment available at most naval shipyards and aboard most tenders and repair ships. If this equipment is not available, the old tubes may be cut

into short lengths inside the shell by use of a power-driven saw, or by other means, and the ends may then be driven out of the tube sheets by the use of a drift. If serious difficulty is encountered in removing expanded tubes, it may be necessary to ream the expanded ends so that only a thin shell remains at the outer surface of the tube.

If a reamer is used, it should be provided with a pilot which closely fits the inside bore of the tube. Regardless of what method is employed to remove the tubes, extreme care should be exercised to prevent damage to the tube holes during the removal operations.

### Renewal of Tubes

Before replacement tubes are installed, great care should be taken that all interior parts of the condenser shell (stayrods, hot well, internal baffles, and joints) are thoroughly inspected. If the joints between the tube sheet and the condenser shell are not in perfect condition, the tube sheets should be removed, the flanges trued, and the joints regasketed. Joints between the stay rods and the tube sheets should be remade and the stay-rod glands repacked. If the tube holes in the tube support plates are larger than specified in condenser plans, corrective measures should be taken to avoid subsequent troubles which may result from the vibration of tubes.

EXPANDING OF TUBE JOINTS. Nearly all condensers installed aboard naval ships have the inlet tube ends expanded in the tube sheet, forming a metal-to-metal joint. In many installations, the outlet tube ends are also expanded. If the condenser tubes are expanded at both ends, it is common practice to provide one or more grooves, or serrations, in the tube holes in order to increase the holding power of the expanded tube joint. Such grooves should be thoroughly cleaned out and burrs removed prior to the installation of new tubes.

The serrating tools used aboard ship should be those furnished by the condenser manufacturer. Tube expanders not

furnished by the condenser manufacturer must meet Navy specifications.

Naval shipyards and repair ships are provided with special types of automatic tube expander controls for expanding condenser and heat exchanger tubes, and for similar operation.

Over-expanding or under-expanding heat exchanger tubes results in later troubles and improper operation. Over-expansion results in excessive cold-worked stresses in the metal, thereby contributing largely to rapid erosion and/or corrosion of the tube end. Under-expansion brings on its attendant burdens of tube leakage, thus requiring reexpansion of the tubes, with the possibility of the ship being handicapped in reliability and operational performance.

Navy specifications require that tube expander rolls be tapered to correspond with the taper of the expander mandrel so as to provide for parallel expansion of the tube wall. The inner end of the rolls should be suitably rounded off to form a torpedo-shaped end, to prevent ridging and cutting of the tubes at the inner end of the expanded joint. In order for a tube expander to be properly set for a given job, it is generally necessary that the over-all length of the rolls be not less than $\frac{3}{16}$ inch, and no more than $\frac{5}{8}$ inch, greater than the thickness of the tube sheet into which the tube is expanded. The expander should be adjusted so that the expanded portion of the tube does not extend completely through the cylindrical portion of the tube sheet hole, and a length of about $\frac{1}{8}$ inch of the tube at the inner end of the tube hole remains unexpanded. If the tubes are expanded completely through the tube sheet, the part of the expanded joint which extends into the condenser, and beyond the support of the tube hole, will bulge and subsequent removal of tubes will be extremely difficult.

After the expanding operation, the inlet ends of the tubes should be belled or flared to an outside diameter of not more than $\frac{3}{4}$ inch for $\frac{5}{8}$-inch OD (outside diameter) tubes, and $\frac{7}{8}$ inch for $\frac{3}{4}$-inch OD tubes.

Flaring tools must not be driven into the tube end so hard

that the wall of the tube is appreciably thinned or cut. It is good practice to mill or grind the projecting flared ends of the newly installed tubes flush with the tube sheet surface in order to provide a smooth entrance for the circulating water flowing into the inlet ends of the tubes. It is not necessary to flare the outlet ends of the expanded tubes, and the tube outlet ends may be allowed to project up to about 1/16 inch from the face of the tube sheet surface.

PACKING OF TUBES. Flexible metallic packing in accordance with Navy specifications should be employed for packing the outlet ends of packed condenser tubes. The inlet ends of the condenser tubes should be fixed in the tube sheet by expanding, prior to the packing of the outlet ends. The old packing must be completely removed and the threads or serrations of the glands should be thoroughly cleared of all packing and foreign matter.

When stuffing box glands are 3/4 inch deep, the proper packing consists of two fiber rings and two metallic rings. To facilitate the installation of packing, a loading pin should be inserted into the outlet ends of the tubes.

After the loading pin has been inserted into the tube end, a fiber packing ring is placed on the pin and driven to the bottom of the stuffing box. Next, a metallic packing ring is placed on the loading pin and calked into the packing box with three or four light hammer blows, to cause the metal to flow into the threads of the gland and remove all slight voids. These operations are repeated by inserting another fiber expansion ring and another metallic ring in the same manner, calking each metal ring separately. If the depth of the stuffing box is greater than 3/4 inch, an additional metallic packing ring should be installed in proper order and calked firmly in place. If the stuffing box is 5/8 inch deep instead of 3/4 inch deep, only three rings of standard packing can be used. In this case, one metallic ring is calked in place at the bottom of the stuffing box, and is followed by a fiber ring and a second metallic ring.

When all tubes have been packed, the condenser is tested by filling the shell with warm water. If any tubes show

leakage at the outlet end, the joint is recalked with light hammer blows applied to the calking tool. Warm water is used for testing, to guard against condensation forming on tube sheets and tubes, and giving a false indication of leakage. Any expanded tube joints which leak during this test should be lightly rerolled.

It is extremely important to avoid excessive use of force in calking the packing. Excessive force applied during packing operation may "neck" the tube end so that the tube is held too tightly in the packing box gland for proper movement through the gland during expansion. When the necked tube moves through the packing, leakage at the joint will result.

If the tube is badly necked during the packing operation, it will grip the loading pin pilot and some difficulty may be experienced in removing the loading pin. Any such difficulty experienced during packing operations is positive evidence that packing has been calked excessively and such tubes should be replaced immediately. Air hammers should not be used for calking flexible metallic packing condenser tube joints, as there is a danger of excessive calking.

## SAFETY PRECAUTIONS FOR CONDENSERS

The following condenser safety precautions should be observed aboard ship:

1. Be prompt in taking corrective measures against all air leaks which may reduce the condenser vacuum.
2. Do not subject the condenser water chests to pressures in excess of 15 psi gage.
3. Whenever condensers are secured, examine the water chest relief valves and lift them by hand.
4. To guard against sea water being introduced into the feed system, operate salinity indicator systems constantly, and run salinity tests every 15 minutes while under way and every 30 minutes while standing by.
5. Keep baffle plates in place under steam inlets to condensers, and maintain them in satisfactory condition.

6. Keep an adequate number of zincs in place, and ensure that they always have good metallic contact.

7. Slow down or stop the engine when a loss of vacuum is accompanied by a hot or flooded condenser.

8. Keep water from accumulating in the steam side of the condenser and overflowing into the turbines.

9. Keep condensers clean and tight.

10. Before the salt-water side of a condenser is opened, close all sea connections tight and secure them against accidental opening.

11. Do not bring an open flame, or anything that might produce a spark, close to a newly opened condenser until the condenser has been thoroughly blown out with steam or air. (Hydrogen or sewer gas may be present.)

12. Avoid "necking" or crimping tubes when packing or calking tube joints.

13. When repairing tube ends or renewing tubes, exercise extreme care to prevent damage to tube sheets.

14. Keep condenser tubes free of sand, seaweed, or other foreign matter.

15. Keep the salt-water sides of idle condensers dry, especially when the ship is in polluted waters.

16. Keep the steam side of secured condensers drained.

17. When condensers are in operation, keep the salt-water sides free from air.

18. See that the condenser headers are ventilated (by portable blowers) before personnel are permitted to enter. (Hydrogen or other gas may have collected in a header.)

19. See that necessary safeguards are provided, when condensers are being boiled out, to protect yourself and others against scalds.

20. Replace and temporarily secure inspection plates whenever work is discontinued.

## DEAERATING FEED TANKS

The major functions of the deaerating feed tank include: (1) provision of a storage reservoir in the feed system to ensure stable operation under rapidly fluctuating load con-

ditions, (2) heating of the feed water to a temperature closely approaching that corresponding to the pressure of auxiliary exhaust steam, (3) deaeration of the heated feed water, and (4) maintaining the reserve supply of feed water in the lower part of the tank in a thoroughly heated and deaerated condition. In the pressure type deaerating feed tank system, final reliance is placed on the deaerating tank for removal of dissolved air from condensate, drains, and other feed water components.

### Operation of the Deaerating Feed Tank

During normal operation, the only control necessary is the proper maintenance of the water level. The absolute maximum operating level, beyond which the units should NEVER be operated, is shown in figure 4–3, at the top of the cone. If the water level is too high, the tank will not function properly in removing air from the feed water. A low water level may endanger the boiler feed pumps.

When operating deaerating feed tanks, remember that steam and water are mixed by spraying the water so that it comes in contact with steam injected into the tank. The

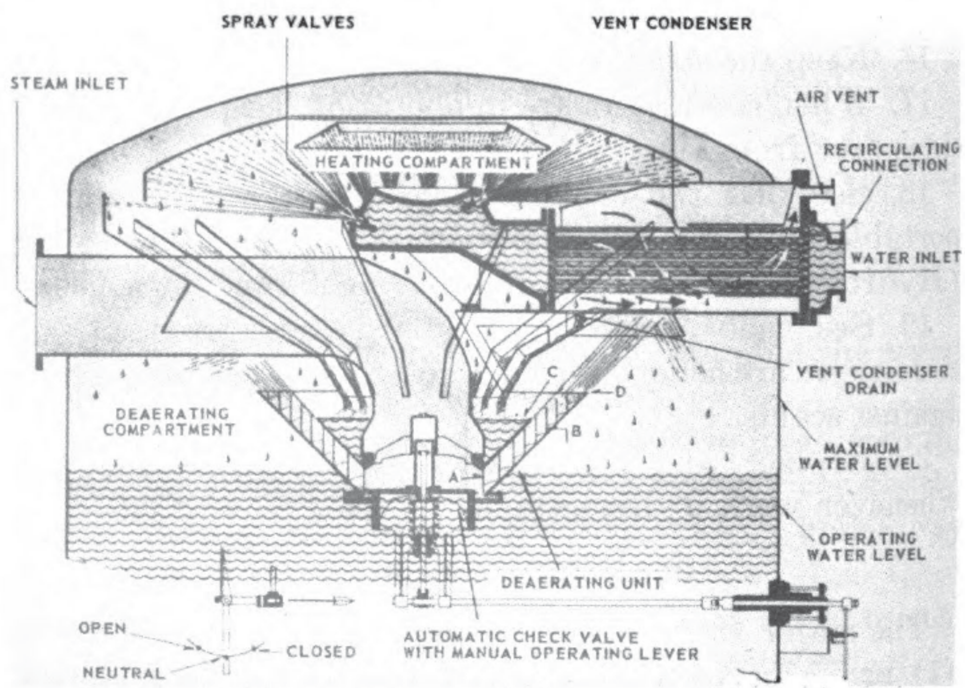


**Figure 4–3.—Deaerating feed tank (diagrammatic arrangement).**

steam flow quantity is always in step with the flow of water. Faulty operation, or an accident, can disturb this relationship. During normal operation of the deaerating feed tank, avoid overfilling and running down, as far as possible; this wastes heat and fuel, and may waste water.

The mixture of condensate, drains, and make-up feed water constituting the inlet water to the deaerating feed tank enters through the tubes of the vent condenser. The water, under pressure, is forced through the numerous spray valves and discharged in a fine spray throughout the steam-filled top, or preheater, section of the tank. The tiny droplets of water are heated and scrubbed by the relatively air-free steam, so that practically all of the dissolved air is released. The drops of water are collected by an inverted conical baffle, which conducts them to a central point. Here the partially deaerated and heated water is picked up by the incoming exhaust steam and thrown radially outward and upward, against the lower side of the conical baffle, in a finely atomized spray. The water is heated essentially to the temperature of the steam, and the dissolved gases which it contains are removed. The water then falls into the storage space at the bottom of the tank, where it remains under a blanket of air-free steam until needed for the boilers.

If a spray nozzle sticks open, or if a spray nozzle spring is broken, the resultant flow from the nozzle will not be in the form of a fine spray and, therefore, deaeration will be impaired. Such a condition cannot be discovered except by analysis of the feed water leaving the deaerating feed tank, or by inspection of the spray nozzles. On ships not furnished with dissolved oxygen test kits, inspection of the spray nozzles should be scheduled at frequent intervals. In most deaerating feed tanks, the manhole provides access for the inspection of spray nozzles; others are so designed that the spray nozzle chamber and the vent condenser must be removed in order to inspect the nozzles.

Auxiliary exhaust steam flows directly into the deaerating unit. A check valve either in the deaerating unit or in the line leading thereto allows the steam to flow from the auxili-

ary exhaust line whenever the pressure within the deaerating feed tank is less than in the exhaust line. The check valve also prevents the return flow of water into the auxiliary exhaust line in case the deaerating feed tank becomes flooded. In the deaerating unit the incoming steam atomizes the preheated water, as described above, heating it to equilibrium temperature and scrubbing from it the last traces of dissolved air. A portion of the incoming steam is condensed in this process, the condensate collecting with the heated and deaerated feed water in the bottom of the deaerating feed tank. The uncondensed steam flows around the conical baffle into the upper (preheated) section of the deaerating feed tank, where it mixes with the incoming water being discharged by the spray head. Here another stage of heating and deaeration occurs, a large proportion of the residual steam being condensed in the process. The remaining steam flows into the shell of the vent condenser where it is further condensed by heating the incoming water passing through the tubes. The condensate from the shell of the vent condenser drains into the heating compartment. The steam not condensed in the vent condenser flows out through the vent line of the vent condenser, carrying with it all of the dissolved air which has been removed from the incoming feed water.

### Warming Up a Deaerating Feed Tank

A secured deaerating feed tank must be kept isolated from the feed water system and its contained water should be deaerated before the tank is cut into the system to supply boiler feed water. If the secured tank is empty, it may be filled by means of the emergency feed pump taking suction from a reserve feed tank and discharging through the starting-up line to the main condensate line, at a point just ahead of the vent condenser. During this operation, auxiliary exhaust should be supplied to the deaerating feed tank in order that the incoming water will be heated and deaerated. In warming a cold deaerating feed tank, the steam and water supply valves should be opened slowly in order to avoid

sudden temperature changes within the tank. When the tank is filled to the normal operating level, a feed booster pump should be used to circulate the water from the deaerating feed tank back through the warming-up line and the vent condenser. It will take about 10 minutes for this recirculation to remove the air from the water in the tank. The deaerating feed tank should be run at normal operating temperature and pressure for about 10 minutes before it is ready to be cut into the boiler feed system.

When the deaerating feed tank is fully warmed up, and before the tank is cut into the feed system, the valve in the warming up line should be closed slowly. During normal operation, the starting-up line should be secured. The feed pump recirculating line is relied upon to protect the booster pump as well as the feed pump from overheating. If the starting-up line is permitted to remain open during normal operation, the large quantity of heated water recirculated through the vent condenser will reduce effectiveness in removing the air vapor mixture from the tank.

### Venting the Deaerating Feed Tank

To secure effective deaeration, it is necessary to vent sufficient steam from the deaerating feed tank to sweep out all

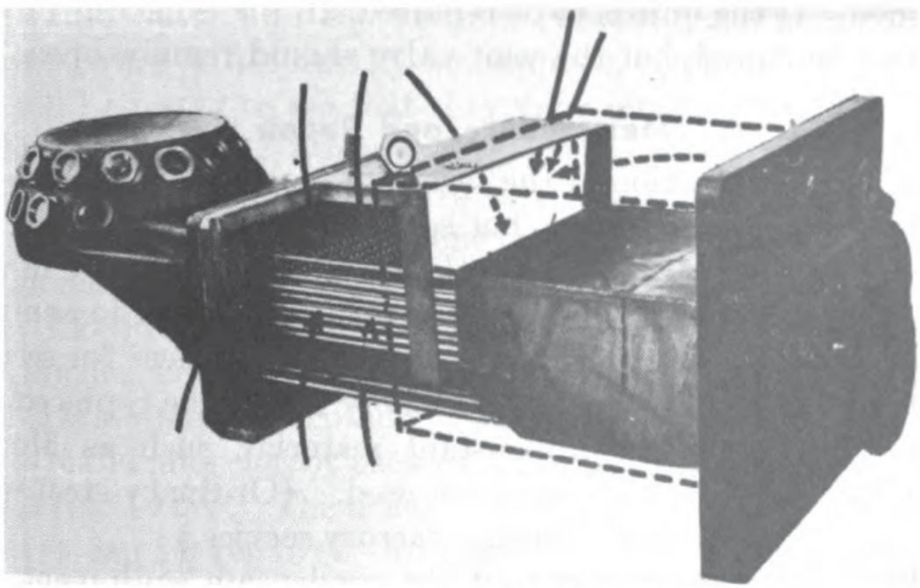

Figure 4–4.—Vent condenser, showing path of gases.

the air which has been separated from the feed water. This separated air is continuously concentrated in the uncondensed portion of the steam, as the steam passes through the deaerating unit, preheater, and vent condenser. If all the steam were condensed in the vent condenser, the separated air would be redissolved in the vent-condenser condensate.

The amount of vented steam is controlled by an orifice installed in the vent-condenser vent line. This vent line orifice must be large enough so that the minimum quantity of steam-air mixture necessary for proper deaeration is discharged when the MINIMUM operating pressure exists in the deaerating feed tank.

A vent condenser, showing the path of gases into the unit, is illustrated in figure 4-4.

### Securing the Deaerating Feed Tank

In securing the deaerating feed tank, the vent valve should be opened fairly wide. The water supply should then be shut down, and the main feed pump and booster feed pump secured. In shutting down the water, watch the steam pressure. If the steam pressure begins to build up, the steam should be throttled. Do NOT shut down the steam first and then the water; the storage space will become filled with cold water. If the tank is to be drained, the drain valve can be opened. If the unit is to be repaired, all the isolating valves should be closed, but the vent valve should remain open.

### Maintenance and Repair

In the construction of the feed tank, as many parts as possible are welded together, but some bolts, nuts, etc., must be used. If any part is dismantled, make certain that, in reassembling, all bolts, nuts, etc., are secured against loosening. Washers and cotter pins are used at various places for securing parts. Cotter pins will probably need to be replaced, in which case a corrosion-resistant material, such as Monel metal or stainless steel, must be used. (Ordinary steel will corrode too rapidly to give satisfactory service.)

If loose parts from any of the condensate equipment, or

from the steam line, get into the booster pump, the pump may be seriously damaged. A screen is provided within the deaerating feed tank, to catch such parts. The screen should be inspected and, if it is damaged, repaired before the deaerating feed tank is placed back into service.

A manhole in the shell gives access to the interior of the deaerating feed tank. All removable parts of the tank section are made in sections small enough to be taken out through this manhole.

The vent condenser can be removed as a unit by loosening its flange bolts and pulling it out. With it will come the spray chamber and constituent parts. It will be necessary to disconnect and clear the water and vent lines before the condenser can be removed.

At regularly scheduled periods, routine inspections of the water spray valves and the check valve should be made. The frequency of such inspections will depend upon the material conditions found and the estimated need of inspections to ensure trouble-free operation, in accordance with good engineering practice. The water spray valves and the check valve should always be maintained in good mechanical and operational condition. A defective valve will interfere with the proper performance of the deaerating feed tank. As found necessary, routine inspections should be made of the relief valve and the vacuum breaker. Although little maintenance will normally be required, these safety devices should be tested to see that they function properly.

Spray Valves. When a spray valve in the spray valve chamber is defective the entire valve can be removed and repaired, or replaced by a new one taken from the ship's spares.

On most installations, when spray valves are reassembled, they should be given an initial compressed spring length of 2⅛ inches, end to end. The threaded stem end of a spray valve is slotted and should be slightly spread after assembly, so that the nuts cannot back off the valve stem.

Check Valve. The deaerating unit is made in 3 pieces so that it can be removed through the access door and easily assembled. In assembling the check valve in this unit, the

inner part of the unit should be bolted to the steam pipe; the dowel in the flange should be fitted to the dowel hole in the steam inlet pipe. The outer parts of the deaerating unit should then be bolted to the inner part of the deaerating unit. The check valve, completely assembled, should then be bolted to the deaerating unit.

In fitting this valve in the unit, care should be taken to see that the piston rings on the dashpot piston are not damaged when they are slipped into the dashpot cylinder. The cylinder has a chamfered end to facilitate easy assembly. When the piston ring is fitted to the cylinder, the clearance between the ends, at the cut, should be between 0.005 and 0.007 inch. This clearance is provided so that the ring will enter the cylinder without binding and breaking. It is important that the piston enter the cylinder squarely and that the piston rings enter evenly to prevent them from binding on the edge. The check valve flange and the deaerating unit are doweled so that the check valve operating lever bearings will be properly located. The fit between this flange and the inner part of the deaerating unit is male and female to ensure proper alignment of the valve. The check valve operating fork, the lever assembly, and the rest of the manual control mechanism can then be assembled. To remove the check valve and the deaerating unit, the above procedure should be reversed.

## AIR EJECTORS

In most ships, the first and second stages of the air ejector and their condensers have been combined into one complete assembly, as shown in figure 4–5. (In many ships, the gland exhaust condenser's functions have been incorporated within the shell of the after-condenser.) The shell is rectangular in shape, and is divided by a longitudinal plate into the inter- and after-condenser sections. A baffle at the gland vapor inlet deflects the air and vapor downward over the lower bank of tubes in the after-condenser section.

In order to provide for continuous plant operation, two sets of nozzles and diffusers are furnished for each stage

of the air ejector. Only one set is necessary for operation of the plant; the other set is maintained ready for use in case of damage or unsatisfactory operation of the set in use. The two sets can be used simultaneously, however, when excessive air leakage into the main condenser necessitates additional pumping capacity. An inter-stage valve is provided between the discharge of each first-stage ejector and

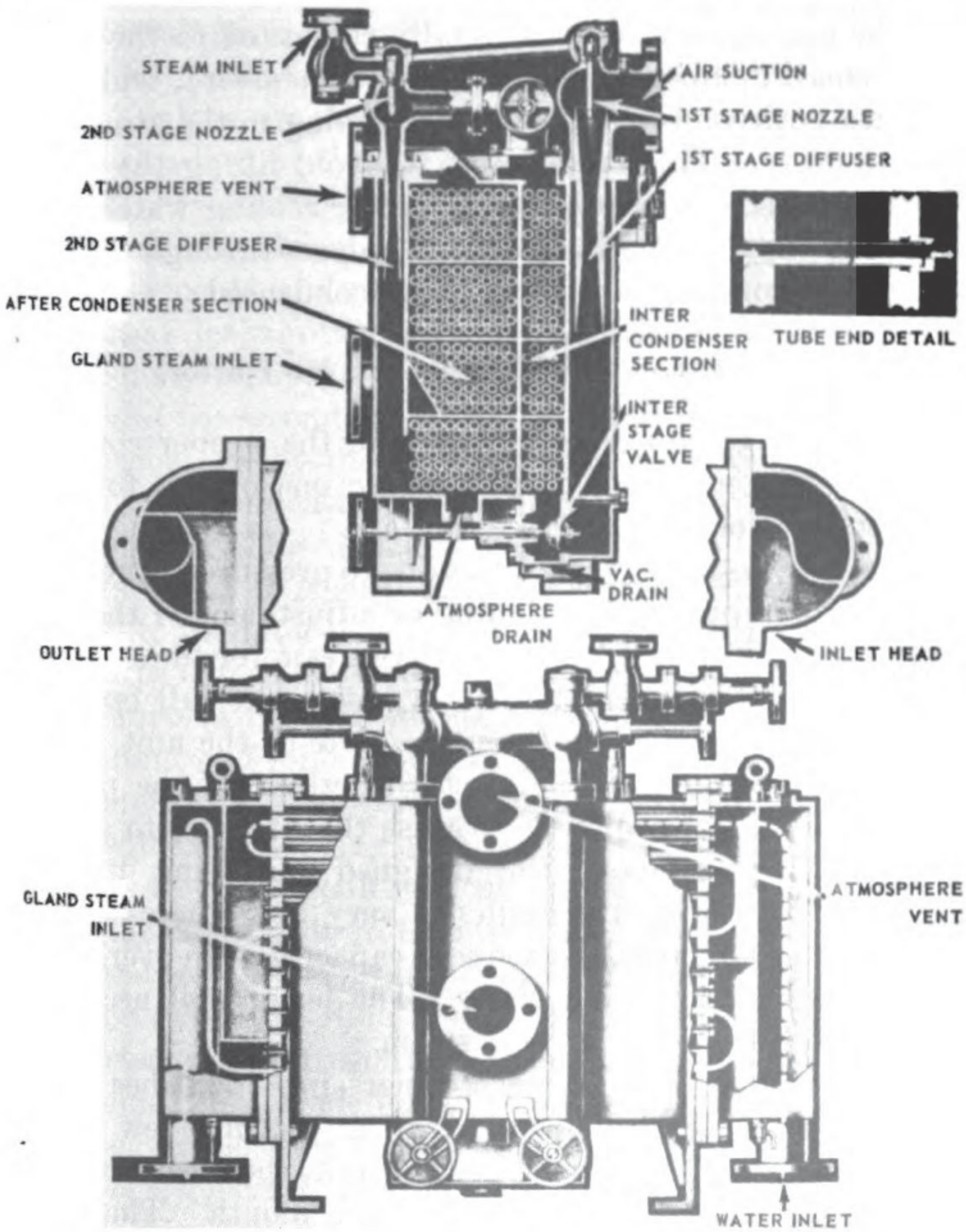


Figure 4–5.—A main air ejector and condenser assembly.

the inter-condenser so that the pressure built up by the first-stage jet, in operation, will not be lost back to the condenser through the idle first-stage ejector. For a similar reason, a cut-out valve is located between each second-stage suction chamber and the inter-condenser. By means of diaphragm plates in the inlet and outlet heads, the cooling water (condensate) is caused to make several passes through the unit before discharging.

The atmospheric vent is usually connected to the suction of a small motor-driven fan (gland exhauster), which provides a positive discharge through piping to the atmosphere above decks. This is desirable to avoid filling the engine-room with steam in case the air ejector cooling water supply should fail, allowing the jet steam to pass through the inter- and after-condensers without being condensed.

## Care and Maintenance of Air Ejectors

If an air ejector fails to maintain the proper condenser vacuum, the cause may be traced to one of the following sources of trouble:

Steam Pressure. Difficulties due to pressure are generally caused by improper functioning or adjustment of the steam reducing valve supplying the motive steam for the air ejector assembly. It is essential that dry steam at full operating pressure, as specified on the name plate of the unit, be continuously supplied to the ejector nozzles. If the pressure fluctuates, it is permissible to raise the pressure to approximately 15 psi above the designed operating pressure. Higher steam pressure results in very little increase in capacity, and may result in reduced capacity or in overloading of inter- and after-condensers. The latter will necessitate an uneconomical quantity of steam.

Steam Strainers. Steam strainers, provided ahead of the nozzles, must be kept clean. During the first few months of operation of a newly connected unit, the steam strainers should be inspected at least once each month. Thereafter, a semiannual inspection of the strainers should be sufficient,

unless there is reason to believe that the strainers are not clean.

In some installations the steam pressure gages, provided to indicate the steam pressure at the ejector nozzles, are actually connected to the system at a point ahead of the strainers. Therefore, if the strainers become clogged, the air ejector may not be functioning properly because of the low steam pressure at the nozzles, even though the gages indicate full steam pressure.

LEAKS. Leaks in valve glands, gasketed joints, relief or sentinel valves, etc., will result in loss of vacuum caused by the overloading of the operating ejector elements.

Leaks through suction or discharge valves of idle or stand-by air ejector elements will also overload the operating ejector elements, and result in loss of vacuum.

Internal leakage across the division plate between the after-condenser and the inter-condenser will result in overloading of the second-stage element, since the air-steam mixture discharged by the second-stage element will leak back to the inter-condenser instead of being discharged to the atmosphere. This difficulty is not common in modern air ejectors but if it is suspected, a hydrostatic test should be applied to the inter- or after-condenser shell, and drains inspected to determine whether leakage exists. Repairs generally involve removal of the condenser tubes, disassembly of the unit, and replacement of the internal gaskets.

TUBE LEAKS. Improper drainage or leaking condenser tubes will cause flooding of the inter- or after-condenser with condensate, with resulting loss of vacuum. Flooding may cause the condensate to be drawn into the second-stage element and result in erratic operation of the unit. If flooding is suspected, drain lines should be inspected and cleared. If necessary, a hydrostatic test should be placed on the unit and examination made for tube leaks, either at the tube joints or through the tube walls. The necessity for replacement of tubes is generally infrequent in view of the fact that most installations involve the use of condensate as the cooling medium. If tube-joint leakage is evident, the packed ends

can be repacked by using copper-asbestos packing rings supplied as a part of the repair parts allowance.

If repacking is required, the removal of the old packing rings and the installation of new ones should be accomplished in the same manner as described for condenser tubes. However, the copper-asbestos rings should be set with a large number of very light blows on the calking tool, as the copper does not flow into the threads of the packing box as readily as does lead. When installing the copper-asbestos packing rings, special care should be taken to avoid "necking" or crimping of tubes. Similar damage to tube ends, resulting from overtightening of ferrules, must be carefully guarded against. Leakage at the expanded ends of the tubes can be repaired by rerolling the tubes. Emergency repair of a leaking tube is accomplished by plugging both ends.

If retubing or other major repairs are necessary, all parts of the air ejector assembly should be tested to the hydrostatic test pressures specified on the name plate. Special care should be taken to see that all internal parts of the assembly are examined and put in proper working order before the new tubes are installed. A positive test should be made, before and after the new tubes are installed, to establish the tightness of the division plate gaskets between the inter- and after-condensers. With certain installations, erosion of tubes may take place in the vicinity of the diffuser discharges. If this trouble is suspected, a sample tube should be withdrawn at a loction close to each jet discharge of the inter- and after-condensers. If inspection shows that serious erosion is present, other tubes in the affected area should be renewed, and periodic inspection and renewal of tubes should be made as required.

Loop Seal. The condensate formed in the inter-condenser is returned to the main condenser through the loop seal. If a direct connection between the inter-condenser and the main condenser were used to return this condensate, the vacuum would be equalized in the two condensers. Since the main condenser is capable of carrying a higher vacuum than that in the inter-condenser, it is necessary to maintain some form

of seal in the drain line to prevent the equalization of vacuum. To provide this seal, a loop seal (see fig. 4–6) is installed in the drain connection.

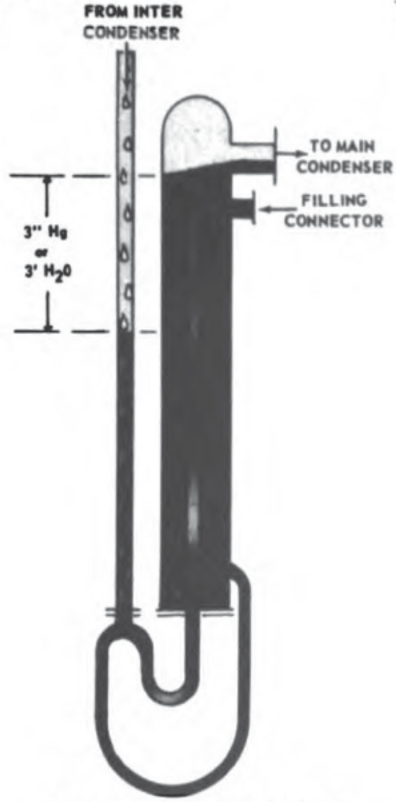


Figure 4–6.—Loop seal.

Water from the inter-condenser passes down through the small 1-inch pipe, then through the short loop, and up through the internal pipe. The larger pipe surrounding the internal pipe is 3 inches in diameter, and is connected to the main condenser. Water overflowing the internal pipe fills the external pipe and the larger loop.

If no vacuum existed in either condenser, and water from the inter-condenser entered the internal pipe, it would maintain the same height in each leg. In other words, when the water level in the external pipe is at the connection to the main condenser, the water level in the primary leg stands at the same height.

However, when a vacuum is formed in both condensers, the difference between the vacuum maintained on the main condenser and that maintained on the inter-condenser will be

(under normal operating conditions) about 3 inches. The vacuum on the main condenser will be about 29 inches, that on the inter-condenser 26 inches. Expressing vacuum in terms of absolute pressure, an absolute pressure of ½ psi will be acting down on the internal and external pipes, and an absolute pressure of 2 psi will work down against the water level in the primary 1-inch pipe. This means that the pressure of 2 psi from the primary pipe will push water through the pipe and cause it to overflow from the external pipe into the main condenser.

When the water level in the primary leg is approximately 3 feet below that of the secondary leg, the additional weight of the water present in the secondary leg will provide the extra 1½ psi necessary to counteract the 2 psi absolute pressure against the primary leg. Thus, a static condition will be obtained. If water is added, from the inter-condenser, to the primary leg, the level on that side will rise, and the additional weight of water on that side will cause water to be pushed into the main condenser, from the secondary leg, thereby restoring the loop to its original static condition.

In this way water is drained back from the inter-condenser to the main condenser by adding water to one side of the loop and removing it from the other side. Thus, a solid body of water is maintained in the base of the loop, and air is prevented from passing through and causing an equalization of vacuum.

The filling connection (shown in fig. 4–6) allows condensate to be pumped directly from the main condenser and discharged into the loop seal in order to provide for positively filling the loop before placing it in operation. A valve is provided at the main condenser to cut off drainage from the loop seal.

If the vacuum gages on both the main and inter-condenser show the same reading, this indicates that the seal has been broken. Opening the filling connection valve for several minutes will correct this condition, if it is due to a sudden surge in vacuum, or a violent roll of the ship. If the condi-

tion is the result of an air leak, this will have to be corrected before the loop will remain properly sealed.

### Air Ejector Nozzles and Diffusers

If air ejector nozzles become eroded, deformed, or fouled, it will be impossible to operate the equipment under high-vacuum conditions. Erosion of nozzles is evidence that wet steam is being admitted to the equipment, and steps should be taken to assure proper drainage of the steam supply lines. If any appreciable amount of water is contained in the motive steam, erratic operation of the entire equipment will result, particularly if the water flows intermittently to the nozzle. If the strainers are not kept clean, the steam pressure differential through the strainer is likely to rupture the strainer basket, admitting dirt or scale to the nozzle. In some cases, nozzles may be clogged with boiler compound or other deposits that will decrease the efficiency of the jet.

INSPECTION AND CLEANING. In general, it is possible to clean the nozzle thoroughly by using nozzle reamers. These should be handled carefully, and the proper reamer used for each size of nozzle, so that the nozzle will not be damaged. If it becomes necessary to remove the nozzle for cleaning or replacement, great care should be taken that the internal surfaces are not damaged. Dents or deformation of the downstream end of the nozzle, and rough or scratchy surfaces in the throat or diffuser passages, will result in improper operation of the equipment. Foreign deposits present on the internal surface of the nozzle or diffusers should be removed by the use of nozzle reamers, or soft copper wire, or a piece of wood.

REPAIRS AND REPLACEMENT OF PARTS. Before disassembly or assembly of nozzles or diffusers is undertaken, plans and instruction books should be consulted. If replacement of a nozzle or diffuser is required, gaskets of proper thickness must be used during assembly. It is essential that the nozzle and the diffuser tube be concentric and in proper alignment and that the correct distance be maintained between the ends of the nozzle and the diffuser. Bear in mind

that first- and second-stage nozzles and diffusers are not interchangeable.

It is possible to clean or replace the steam strainers, nozzles, and diffusers of an air ejector element while the remainder of the assembly is in operation. However, extreme care must be taken that the unit to be opened is first isolated from the assembly by closing the steam supply valve and the inter-stage isolating valves of this element, in order to avoid burns being suffered by personnel engaged in this work. In installations where separate inter- or after-condensers are provided for each element, isolating valves are not required. In some cases where a common after-condenser is provided for two second-stage elements, the internal construction of the unit is such that the steam discharged from the operating element cannot readily back up through the diffuser of the other second-stage element, and isolating valves are omitted from the second-stage diffuser discharges.

### Steam Reducing Valves

The reducing valves for the main air ejectors are the most important ones used aboard ship. In general, all reducing valves should be inspected, cleaned, and repaired semi-annually.

Causes of Faulty Operation. The principal causes of faulty operation of reducing valves are as follows:

1. The adjusting spring has taken a permanent set. Readjust or install a new spring.

2. In case of failure or deformation of the diaphragm, install a new diaphragm. In case of deformation within limits, readjust the diaphragm spring. It is considered good practice to invert the diaphragm periodically, thererby prolonging its serviceability. Diaphragms furnished by the manufacturers of the particular air ejector installation should be used.

3. Leakage is frequently due to the pilot or the main valve not being tight. This trouble is most prevalent in lines

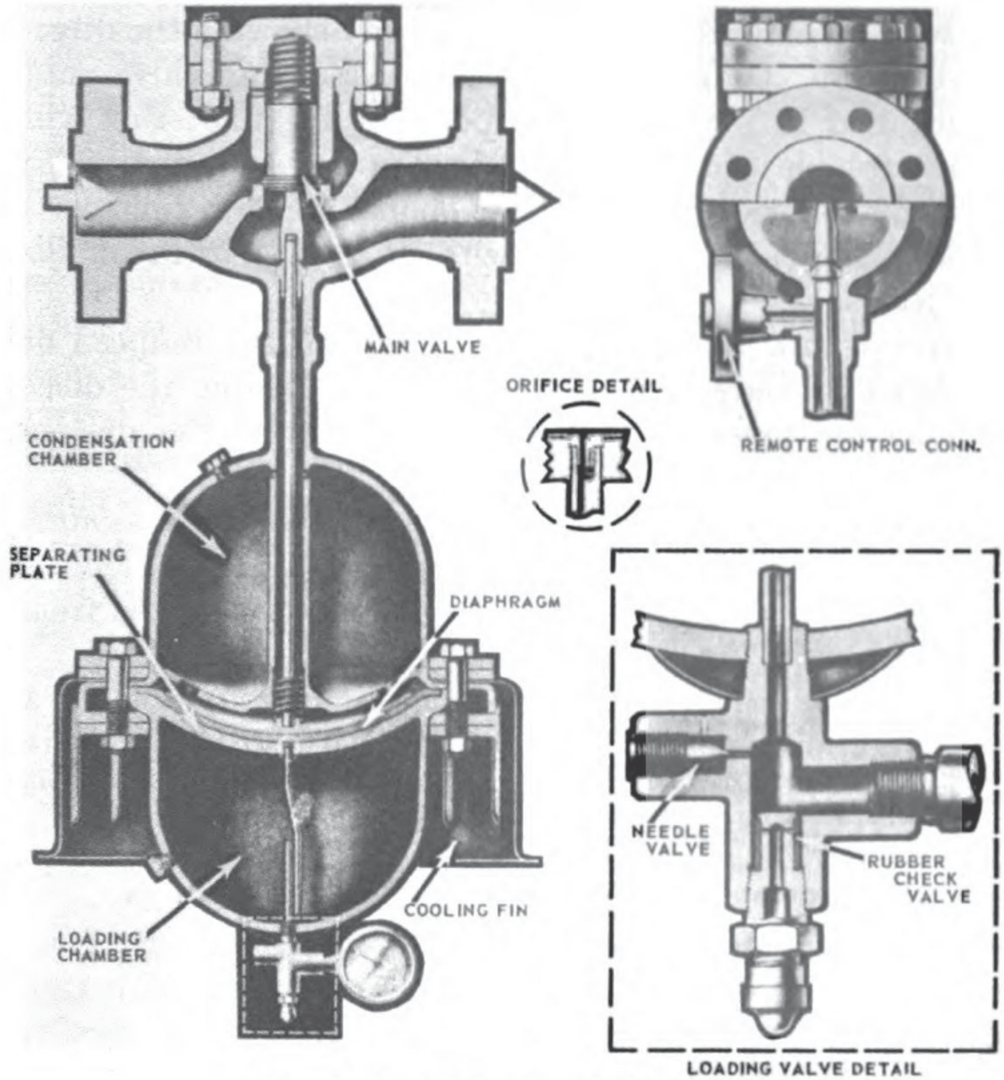


**Figure 4–7.—Details of reducing valve.**

supplying machinery which requires steam intermittently. When the need for steam is reduced, the pressure will build up, due to the leak past the valve. In case of a bad leak, the trouble will be apparent under all conditions. The valve may be held off the seat by scale or dirt, in which case scoring or erosion will probably result. Clean the valve and grind in place.

4. Other causes of failure are working parts or ports gummed with oil or dirt, piston rings stuck, pilot valve stem too long because of successive grinding in the pilot valve, broken or permanently set springs.

Most reducing valves are installed in a vertical position,

and have an arrow cast on the valve body showing the direction of flow. To obtain best results, a reducing valve must be installed in the uppermost point of the line; this will reduce trouble caused by entrained water and dirt. The valve must be located so that the bonnet and working parts of the valve can be removed without having to break the pipe joints.

Setting the Reducing Valve. Setting the reduced or regulated pressure is simply a matter of loading the dome with an air pressure approximately equal to the desired pressure.

Tighten the needle type dome bleed valve firmly against its seat with an Allen wrench. (See fig. 4–7.)

Remove the loading fitting cap and connect the hose from the hand pump.

With slow, full strokes of the pump, charge the dome to a pressure approximately 10 psi above the reduced pressure desired. (If the required reduced pressure is 150 psi, charge the dome until the gage reads 160 psi.)

### Thermostatically Controlled Recirculating Valve

Recirculation is thermodynamically uneconomical; however, in naval installations (where cruising power may normally be only a small fraction of full power) recirculation is essential in order to avoid excessive loss of feed water as vapor discharged from the air ejector after-condenser vent, and to ensure proper operation of the air ejectors at fractional power. To make recirculation automatic and to avoid excessive recirculation with attendant excessive loss of heat, most air ejector recirculating lines are fitted with thermostatically controlled valves.

Excessive heat loss can be avoided by recirculating condensate from the air ejector discharge line back to the main condenser. The air ejector condensers must be supplied with cooling water (condensate) before and during their operation. A hand-controlled valve allows bypassing of the thermostatic recirculating valve during the warming-up period. This bypass valve is also used in case the thermo-

static valve is inoperative. When the required condenser vacuum is obtained, the manually controlled bypass valve is closed.

Under normal operating conditions, recirculation to the main condenser at light loads is automatically controlled by the thermostatic recirculating valve.

Operating Principles. The thermostatic recirculating valves are actuated by the temperature of the condensate discharged from the air ejector after-condenser. Rise of water temperature above the temperature at which the valve is set results in automatic opening of the valve, and recirculation of the heated water back to the condenser and through the air ejector again. The thermostatically controlled recirculating valves are adjusted through a range of approximately 40° F and should be individually set to open at the highest temperature at which the air ejectors will operate without loss of condenser vacuum, or discharge of an appreciable amount of vapor from the air ejector after-condenser vent.

In the interest of economy, the thermostatically controlled valves should be kept in good condition and properly set. Under all normal operating conditions, the manual bypasses should be kept closed. The control bulbs of the valves should be located in the condensate line as close as possible to the after-condenser discharge, or, preferably (when space is available), within the last pass of the air ejector after-condenser water chest.

Figure 4–8 illustrates a thermostatic recirculating valve.

Maintenance of Valve. Failure of the valve to maintain the cooling water at the desired temperature is an indication of improper adjustment. It may also be an indication that the thermostatic elements of the valve are leaking, or that some other portion of the valve has failed.

The main cause for improper adjustment of the valve is the lack of instructions for the proper adjustment procedure. Operating personnel should become familiar with the procedure for adjustment of this type of valve; it is recommended that they consult the manufacturers' instruction books.

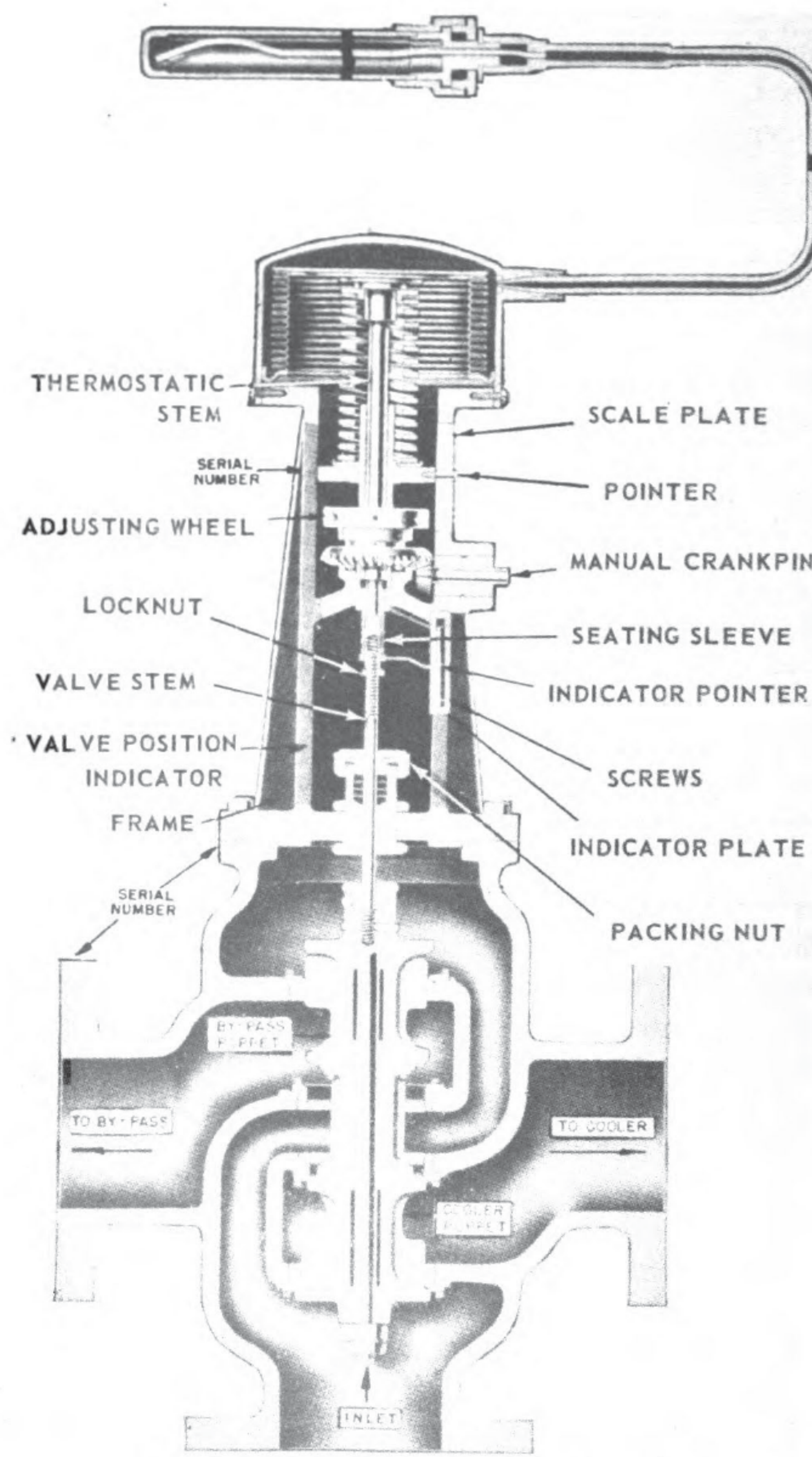


Figure 4-8.—Thermostatic recirculating valve.

Briefly, the adjustment consists of changing the tension of the spring which opposes the action of the thermostatic bellows. An increase in spring tension will require a higher temperature to be reached before the valve will act to divert a greater portion of the condensate to the condenser.

However, when placing a new valve in service, a number of steps must be taken to ensure that the valve stem length will be proper, and that all pointers will be accurate in their indications. All adjustments should be made with the thermostatic control unit assembled on the valve body. When making adjustments it is not necessary to remove the valve body from the ship's piping.

All adjustments must be made in accordance with the following steps and in the same sequence. Make adjustments 1 through 4 with the thermostatic bulb removed from the ship's piping and see that the bulb temperature is below 100° F.

1. Rotate the manual crank pin until the indicator pointer is in the THERMOSTATIC position. Turn the adjusting wheel until the adjacent pointer matches with number 2 on the scale plate. Loosen the locknut and unscrew the valve stem until it is free of the thermostatic stem.

2. Turn the adjusting wheel until the adjacent pointer matches with number 8 on the scale plate.

3. Rotate the manual crank pin again, until the lower end of the seating sleeve is flush with the lower end of the thermotsatic stem. With the seating sleeve and the indicator pointer in this position, loosen the screws in the indicator plate and slide the plate up or down, as necessary, to align the THERMOSTATIC mark in the center of the plate with the indicator pointer. Then retighten the screws. (The marks COOLER CLOSED and BYPASS CLOSED on the indicator plate are only approximate.)

4. Screw the valve stem into the thermostatic stem and turn the stem until the cooler poppet valve is seated firmly. Turn the adjusting wheel until the pointer matches with number 2 on the scale plate. Then rotate the valve stem one

full turn farther ($\frac{1}{16}$-inch) into the thermostatic stem, and tighten the locknut.

5. Turn the adjusting wheel, with the manual control on THERMOSTATIC position, in a direction to bring the pointer to number 9 on the scale plate.

6. Run the condensate pump water until the temperature rises to the desired level.

7. With the condensate pump running and the temperature at the thermostatic bulb maintained at the value determined for step 6, turn the adjusting wheel until the cooler poppet just begins to leave its seat, as shown by the downward movement of the mark on the valve stem.

Valves adjusted in accordance with this procedure will normally maintain the temperature of the water at the thermostatic bulb between the temperature determined for step 6 and a temperature approximately 20° F. higher. This 20° F. difference is the temperature rise required to cause the poppet valve to move through the necessary travel.

## LUBRICATING OIL COOLERS

Oil coolers should be operated as required to maintain the oil inlet temperature to the bearings at the designed valve. With the bearing orifices or needle valves properly adjusted and the bearings in proper operating condition, a temperature of 120° to 130° F. on the discharge from the cooler should satisfactorily meet all normal operating requirements.

When the system has more than one cooler, the coolers should be used alternately, and for approximately the same number of operating hours. When oil coolers are not in use for more than 24 hours, the salt-water side should be kept drained.

### Derangement of Lube Oil Coolers

Plate tube, strut tube, and wire-wound tube coolers are equipped with cores. Ships are allowed replacement cores, or case and core assemblies, as on-board repair parts. These repair parts should be utilized in the event of a major casualty to these coolers, and action to replenish on-board allowance

should be initiated. (In such cases, cores can be requisitioned as "not in excess" items through repair parts channels.) It is estimated that 99 percent of major failure problems on these coolers can be solved by core replacements rather than by replacing the complete cooler assembly.

When derangement of a lubricating oil cooler occurs, the number of hours which the cooler has been in operation is a factor of particular interest to activities attempting to determine the cause of failure. If the cooler has been subjected to an acid cleaning, this fact is similarly of interest because of the possibility of damage to tubes when acid is used.

### Care and Maintenance of Lubricating Oil and Jacket Water Coolers

With reasonable care the lubricating oil and jacket water coolers installed in naval ships should be serviceable for at least 4 or 5 years. When sea water is used as the cooling medium of this type of equipment, failure is primarily due to (1) erosion due to high sea-water velocity, and (2) corrosion due to electrolytic (or galvanic) action.

All coolers are built in accordance with BuShips current specifications. These specifications are designed to give adequate cooling with sea-water velocities well below that which will cause appreciable erosion. Protection against corrosion, however, is provided by the installation of zincs.

Reports of failure of this type of equipment are rare in comparison with the number of coolers of similar construction installed in naval vessels. In general, these cooler failures have been reported by isolated vessels or by vessels of a class built at some particular activity. With few exceptions, they have occurred to coolers supplied with sea water from a service main, with the supply of sea water available to the cooler limited only by a valve (sometimes an orifice), in the cooler supply line. Under these conditions, too wide an opening of the valve, too large an orifice, or too high a pressure in the service main will cause excessive velocity through the cooler and consequent failure due to erosion. At the same

time the oil temperature is usually not appreciably lower than that obtained with proper sea-water flow.

All coolers in contact with sea water are subject to corrosion. Under operating conditions, this corrosion can be taken up by the zincs, provided an adequate surface of the latter is exposed. All zincs installed in the sea water circuit of condensers and heat exchangers must be thoroughly scaled at least once a month to ensure that active metallic zinc is exposed to the sea water.

Of the two causes of cooler failure, the more likely one is erosion from high-velocity sea water. To get satisfactory service from these coolers, the following points should be remembered:

1. Limit the sea-water flow to the MINIMUM that is consistent with maintaining the lubricating oil temperature within limits specified by BuShips *Manual* or by the manufacturer's instruction book, as applicable.

2. Inspect and clean zincs regularly. Replace the zincs when they are 50 percent disintegrated.

3. When securing a cooler for any extended period, drain the salt-water side and flush with fresh water, when practicable. At all other times the cooler should be kept flooded and periodically flushed with salt water.

4. Clean only in a manner prescribed by BuShips.

All the above precautions also apply to other heat transfer equipment, such as refrigerating plant condensers, motor and generator air coolers, air compressor inter- and after-coolers, etc., that use sea water as the cooling medium.

## Cleaning Lubricating Oil Coolers

As a result of battle damage, or for some other reason, a lubricating system (including the cooler) may become contaminated with salt water. No attempt should be made to put such a system back into operation without thoroughly cleaning the cooler to remove all traces of rust, scale, or other foreign matter, since serious damage can result from incomplete removal of such material.

In the case of shell-and-tube coolers, all rust, scale, etc., must be removed, prior to reassembly, from the inside of the shell and from the baffles. Removal should be done with scrapers and/or wire brushes. When complete tube bundles are removed, the necessity for dismantling individual bundles must be determined by visual inspection.

With proper use of lubricating oil purifiers, filters, and strainers, it will ordinarily be necessary to clean only the salt-water sides of shell-and-tube type coolers. This should be accomplished by air- or water-lancing supplemented, if necessary, by the use of rubber plugs and a round bristle brush. UNDER NO CIRCUMSTANCES SHOULD A WIRE BRUSH BE USED FOR THIS PURPOSE.

Removed tube bundles can be cleaned, when necessary, by flushing them with hot water. However, no attempt at chemical cleaning of shell-and-tube type coolers should be made without specific approval of BuShips.

## SUMMARY

Under conditions of warming up, standing by, getting under way, cooling down, and securing of turbines, the condenser vacuum should be regulated in accordance with instructions found in BuShips *Manual* and in the manufacturer's instruction book.

Know the importance of cleaning the fresh- and salt-water sides of condensers and what procedures to follow under existing conditions. Rememl r that condenser tube leakage can be minimized by proper maintenance of condensers.

Retubing of condensers may be necessary when the number of failed tubes exceeds 10 percent of the total number. When condenser tubes have to be replaced, authorization must be obtained from BuShips. Subject to approval of the type commander, the retubing of auxiliary condensers may be performed by forces afloat or by a naval shipyard, without obtaining authority from BuShips. Remember that all interior parts of the condenser shell must be thoroughly inspected before replacement tubes are installed.

When operating deaerating feed tanks, remember that steam and water are mixed by spraying the water so that it comes in contact with steam injected into the feed tank. Never try to dismantle a deaerating feed tank or make repairs without proper authorization and without referring to the manufacturer's instruction book.

The air ejector steam strainer should be inspected regularly and cleaned when necessary. Failure to keep the strainer clean, and clogging or scoring of the air ejector nozzle, will result in a reduced and fluctuating vacuum.

Remember that if a lubricating oil cooler becomes contaminated with salt water, the cooler should be thoroughly cleaned to remove all traces of foreign matter.

## QUIZ

1. The difference between the temperature of the condensate discharge and the temperature corresponding to the vacuum maintained at the exhaust inlet to the condenser is referred to as what?
2. Under normal operating conditions, when should the inlet tube ends of main condensers be examined?
3. How may tube erosion from the auxiliary exhaust dumping lines be prevented?
4. How should the steam side of a condenser be kept when the condenser is secured?
5. Under normal operating conditions, how often should the salt-water side of the condenser be inspected?
6. Under normal operating conditions, how often should the steam side of a condenser be inspected?
7. What are the probable causes of a noise heard inside the inlet header of a condenser?
8. How may foreign matter on the steam side of a condenser be removed?
9. Under normal conditions, how often should condensers serving turbines require boiling out?
10. What is the most common cause of condenser tube leaks?
11. In general, what is the maximum percent of the total number of tubes that can be plugged without seriously affecting the operation of the condenser?
12. What parts of the condenser should be thoroughly inspected before replacement tubes are installed?
13. What are the results of over-expansion of heat exchanger tubes?

14. If any condenser tubes show evidence of leakage at the outlet end, after the tubes have been packed, what should be done?
15. Condenser water chests should not be subjected to pressures in excess of how many psi?
16. What should be done when a loss of vacuum is accompanied by a flooded condenser?
17. What should be avoided when packing or calking tube joints?
18. In warming up a cold deaerating feed tank, what step should be taken to avoid sudden temperature changes within the tank?
19. What is installed in the vent condenser vent line to control the amount of vented steam?
20. If spray valves are taken apart, they should be reassembled to give an initial compressed spring length, end to end, of how many inches?
21. How often should an air ejector steam strainer be inspected?
22. What will be caused by flooding the inter- or after-condenser with condensate brought about by improper drainage or leaking condenser tubes?
23. How often must the reducing valves of air ejectors be inspected, cleaned, and repaired?
24. In order to obtain best results, where should a reducing valve be installed in an air ejector assembly?
25. Under normal operating conditions, recirculation to the main condenser, at light loads, is automatically controlled by what unit?
26. If the bearing orifices are properly adjusted, what temperature range on the discharge from the lubricating oil cooler will meet normal operating requirements?
27. What are the two chief reasons for lubricating oil cooler failures?
28. When should zincs installed in lubricating oil coolers be replaced?



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# CHAPTER 5

## SHIP'S SERVICE TURBOGENERATORS

In the preceding chapters of this training course, you have been given some information that is applicable to turbogenerators. This chapter deals with the operation, inspection, and maintenance of turbogenerators.

### TURBINE GOVERNOR SYSTEM

Ship's service generators supply electricity for lighting and power throughout the ship. Since a constant voltage and frequency must be maintained on the ship's service lines, the generator turbine operates at a constant speed. This speed is maintained at a predetermined rate—regardless of load and exhaust pressure conditions—by means of a constant-speed governor. Other control features include (1) an OVERSPEED TRIP, which closes the throttle if the speed regulating governor fails to operate and the turbine overspeeds, (2) a BACK-PRESSURE TRIP, which closes the throttle if excessive exhaust pressure is built up, and (3) a MANUAL TRIP, which makes it possible for the throttle to be closed quickly in case of damage to either the turbine or the generator.

A typical ship's service generator governor system (fig. 5–1) consists of a centrifugal governor which operates a pilot valve controlling the flow of oil to the operating cylinder. In turn, the cylinder piston controls the amount of opening or closing of the turbine nozzle valves, through which steam is admitted to the turbine.

The gear type oil pump and the main speed governor,

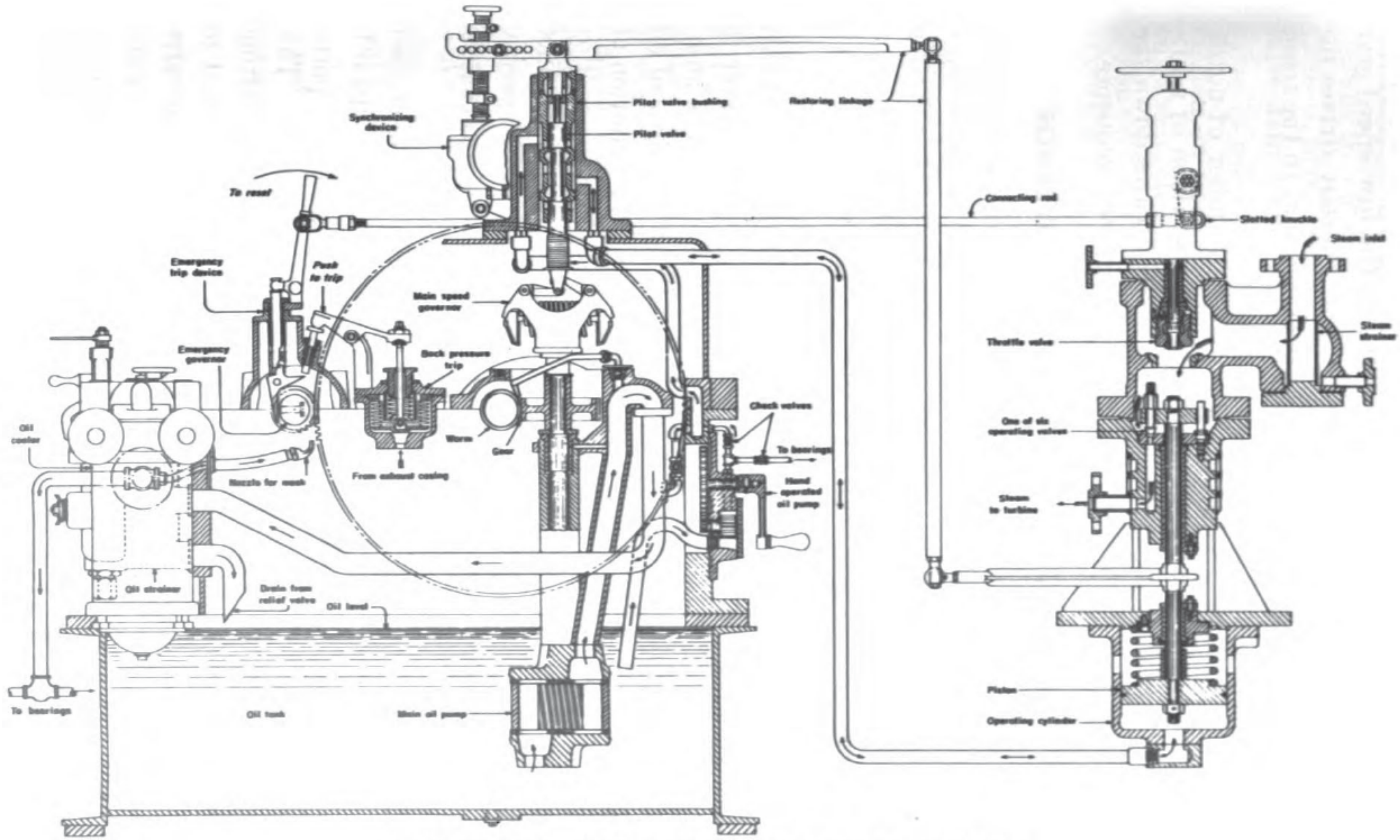


Figure 5–1.—Ship's service generator governor system.

mounted on the same shaft, are driven through a worm and gear. The worm is directly connected to the low-speed gear shaft of the turbine reduction gear, and thereby drives the governor at a speed that is directly proportional to the speed of the turbine.

Speed control is affected by varying the number of nozzle control valves that are open, through the operation of a lifting beam mechanism; as the beam is moved up and down, the nozzle valves open and close in a predetermined sequence.

## OPERATION OF THE MAIN SPEED GOVERNOR

When the turbine tends to slow down, because of an increased load on the generator, the governor weights move inward and cause the pilot valve to move upward, allowing oil to enter the operating cylinder. This causes the operating piston to rise and, through the controlling-valve lever, raises the lifting beam, opening the nozzle valves and admitting additional steam to the turbine. This upward motion of the controlling-valve lever causes the governor lever to rise, thus raising the bushing. Upward motion of the bushing tends to close the upper port, shutting off the flow of oil to the operating cylinder; this stops the upward motion of the operating piston. The purpose of this follow-up motion of the bushing is to regulate the governing action of the pilot valve. Without this feature the pilot valve would operate, with each slight variation in turbine speed, to alternately fully open and fully close the nozzle valves.

When the turbine tends to speed up, because of a decreased load on the generator, the governor weights move outward, moving the pilot valve downward, opening the lower ports, and allowing oil to flow out of the operating cylinder. This action causes the controlling-valve lever to lower the lifting beam, thereby reducing the amount of steam delivered to the turbine. The downward motion of the controlling-valve lever causes the governor lever to lower; this lowers the bushing. The downward motion of the bushing tends to close the lower port, preventing oil from flowing out of the operating cylinder.

The other three control devices mentioned earlier (the overspeed trip, the back-pressure trip, and the manual trip) all operate to close the throttle and emergency valve. This valve is fitted with a special device which disengages the valve stem from the handwheel operating gear whenever the valve is tripped. This action allows the spring pressure exerted on the top of the valve disk to force the disk down on its seat, closing the valve.

The overspeed trip is operated by the emergency governor (shown in fig. 5–1) mounted on one end of the shaft. It consists essentially of a plunger, which is held in place by a spring. As the plunger moves out, it strikes the trigger, which trips the trip rod, causing the bell crank to move to the right. This motion, in turn, causes the throttle valve to close by forcing the valve stem down.

The excessive back-pressure tripping device consists of a bellows and spring arrangement, connected to the exhaust casing of the turbine. If excessive back pressure is built up in the casing, it will overcome the compression of the spring and cause the lever to operate the manual trip. The manual tripping device operates the trigger in the same way as the emergency governor, closing the throttle. If it becomes necessary to stop the turbine quickly, the manual tripping device may be operated by hand.

## OPERATION OF THE GENERATOR TURBINE

When a generator turbine is started, it is subject to variable expansion movements because of changing temperature and load conditions. Therefore, when a turbine is being put in service, a reasonable amount of time should be spent in warming it, gradually increasing the speed and applying the load.

### Starting the Turbine

When starting a turbine driving an electric generator, the following procedure is recommended:

1. See that the oil in the tank is well above the normal operating oil level.

2. Open the drain ahead of the throttle valve.

3. Leave the drain ahead of the throttle valve open for a short time until the condensate is discharged.

4. Start the condenser pumps (condensate pumps, air ejector, and circulating pumps).

5. Open the turbine exhaust to the condenser.

6. Bring the vacuum to about 15 inches Hg.

7. Operate the hand oil pump sufficiently to move the piston of the steam control valves upward, thus admitting steam to the turbine. The hand pump supplies oil to the bearings at the same time.

8. Open the throttle valve. As soon as the turbine is started, trip the emergency tripping mechanism by hand to see that it operates properly.

9. Close the throttle valve, reset the tripping mechanism, and reopen the throttle only enough to keep the turbine rotor rolling slowly.

10. Admit gland sealing steam to the high-pressure and low-pressure packings.

11. See that there is no indication of rubbing of the shaft packing or rotor, while the rotors are revolving slowly.

12. Open the throttle valve wider and gradually increase the turbine speed so that the low-pressure oil gage indicates approximately 4 psi.

13. Watch all bearing oil temperatures and, during the accelerating and warming-up period, listen carefully for any rubbing, vibration, or other unusual noise. Do not continue operation until the cause of any trouble has been determined and corrected.

14. Cut in the circulating water to the oil cooler when the oil temperature of the bearings reaches approximately 110° F. Regulate the flow of cooling water to suit the conditions.

15. Increase the turbine speed to operating speed when the unit is satisfactorily warmed up.

16. Close the turbine drains and increase the vacuum as much as conditions will permit.

17. Open the throttle wide, as soon as the normal speed is reached and the machine is controlled by the speed governor, and retest the operation of the emergency tripping device.

18. Close the throttle valve about ½ turn; this will prevent the sticking of the throttle valve which may be caused by expansion.

### Synchronizing Generators

Aboard large vessels, the ship's electrical load is shifted from one generator to another in order to obtain an approximately equal distribution of running time. Each time the load is shifted, the incoming generator must be synchronized with the other generator(s) being operated. (Two generators operating in parallel, or in step with each other, are said to be synchronized.) As soon as a turbine which has just been started is controlled by the main speed governor and operating satisfactorily, the Electrician's Mate will synchronize the generator with the synchronizing device (fig. 5–1), and connect it to the system.

In paralleling two a-c generators, three factors are involved: voltage, frequency, and phase relationship. The synchroscope measures the difference in the phase angle and the frequency, at every instant, between the incoming generator and the operating unit; it shows when the coupling device must be closed.

To synchronize an incoming generator with an energized unit, the procedure is as follows:

1. Adjust the control devices of the incoming machine to secure normal speed and voltage, and place the voltage regulator in control.

2. Check the voltage of the operating unit and of the incoming unit; turn the rheostat of the voltage regulator until the voltage of the incoming generator is the same as that of the operating unit.

3. Connect the synchroscope across the operating unit and the incoming unit. Depending upon the difference in the

frequencies of the two units, the pointer will rotate in one direction or the other.

4. Manipulate the control switch until the pointer moves slowly in the clockwise direction. When it passes through the zero position, close the generator breaker.

By means of the synchronizing device, a light load is applied gradually to the generator that has just been brought in. After the exhaust casing has cooled, additional load can be applied as desired.

### Running the Turbine

The following steps should be observed during the operation of a turbine:

1. See that the water is circulating in the oil cooler.
2. See that air is circulating in the generator and exciter.
3. See that the oil pump delivers an adequate supply of oil to the bearings and operating cylinder.
4. Adjust the hand valves on the steam seal manifold, in accordance with the manufacturer's instructions.
5. Determine, at periodic intervals, the temperature of the bearings. A satisfactory running temperature of the return oil is 140° to 170° F. The maximum temperature should not exceed 180° F. The temperature rise of oil through any bearing should not exceed 50° F. A log should be kept of bearing oil temperatures.
6. Inspect the lubrication system, making sure that all parts are working properly.
7. Check the vacuum to see that the condenser is operating properly.
8. Keep the valve-lifting rod free from dirt at the guides, so that the mechanism will operate smoothly.
9. Clean and oil the spindle of the throttle valve, and the connections between the levers of the governing mechanism, using a light, heat-resisting oil to prevent gumming.

Make sure that the emergency devices are in proper operating condition; otherwise, the turbine should be stopped immediately.

### Securing the Turbine

When a turbine is to be secured, the procedure is as follows:

1. Decrease the load gradually to a minimum.
2. Trip the circuit breaker.
3. Turn the voltage regulator switch to MANUAL.
4. Cut in all the resistance in the generator field circuit, and all the resistance in the exciter field circuit, by means of the rheostat handwheel.
5. Shut off the cooling water and turn on the heaters, if they are provided.
6. Trip the throttle valve by pressing on the manual-trip button, at the emergency tripping device.
7. Close the stop valve ahead of the throttle valve and open the drain ahead of the throttle valve.
8. Close the turbine exhaust to the condenser.
9. After operating the air ejector continuously for 20 minutes, stop the air ejector, the circulating pump, and the condensate pump.
10. Open the drain ahead of the throttle valve.

When the turbine is shut down, even for a short time, take every precaution to guard against steam bleeding into the turbine casing. When the unit is restarted, bring it up to speed with the same care that is exercised when starting cold.

## INSPECTION, MAINTENANCE, AND REPAIR OF TURBOGENERATORS

Successful operation of turbogenerators depends largely upon the care and attention given the units or equipment. Maintenance should be performed in accordance with manufacturers' and BuShips instructions.

### Care of Generator Turbines

After each period of steaming, and at least once each quarter, the turbine foundation and the unit itself should be carefully inspected for loose and broken nuts and bolts. Such nuts or bolts should be tightened immediately, or renewed.

Concurrently with the above examination, care should be exercised to inspect the turbine casing, especially near glands and in all locations where water may collect in pockets or under the lagging. Experience has shown that where water or dampness is permitted to remain in contact with the casings, corrosion may seriously weaken the casings before it is discovered. Drain holes provided in pockets must be kept open and should be of such size that they are not easily stopped up. When corrosion is evident, the lagging should be removed, if necessary, and the affected surfaces bared and cleaned to good metal. The exposed surfaces should then be dried and painted with two coats of approved paint. Lagging should then be replaced and practicable steps taken to prevent recurrence of corrosion.

All sliding contacts and pivot points in the governor and overspeed tripping mechanisms should be kept free, clean, and well oiled, so that there will be no sticking; otherwise, the safety devices will not function properly at the set speed of rotation. The condition of the split pins, or other securing devices or overspeed tripping mechanisms, should be inspected carefully.

When a turbine is new, or after extensive repairs have been made to a unit, the oil in the reservoir must be renewed or renovated frequently. At other times, the oil must be renewed or run through the purifier frequently. When it is necessary to flush out the system, operate the turbine slowly for several minutes, using an approved flushing oil to thoroughly clean out all lines, bearings, pockets, etc. Then drain off the flushing compound and fill the reservoir with clean oil.

## Inspection of Gear Teeth

A visual inspection of the tooth contact of the pinion and gear should be made periodically and a record as to the condition of the teeth should be maintained on the Machinery History Card.

Uniform distribution of wear over the entire length of both the gear and pinion teeth is an indication of correct

tooth contact. Any deviation from this condition may indicate misalignment of either the gear casing or the connecting shafts. When misalignment is indicated, all available information should be entered in the Current Ship's Maintenance Project (CSMP), so that a work request can be made for naval shipyard repairs. In an emergency, repairs can be made by tender or repair ship.

Examine the gear teeth and the pinion for pitting, and remove any noticeable high spots caused by abrasions from foreign matter passing through the mesh. This may be done with a very fine grade of carborundum stone. Do not use a file or scraping tool; either of these tools may easily damage the tooth contour.

### Care and Operation of the Lubrication System

In connection with the lubrication system, the following recommendations are suggested:

1. See that the oil and lube system are clean and the proper oil level maintained.
2. Maintain an ample reserve supply of oil for emergency use and for making up the deficiency as required.
3. Take samples of oil from the oiling system periodically and have them analyzed.
4. Do not allow water to mix with oil. If water accumulates, it can be removed by draining from the bottom of the tank or by centrifuging the oil. An inspection should be made to determine the source of water and eliminate the cause.
5. See that the pressure gages are registering properly and that the gage cocks, if used, are throttled sufficiently to reduce needle vibration and consequent wear on the internal gage mechanism.
6. Test the oil cooler periodically for water leaks.
7. Maintain the pump, cooler, strainer, and other appliances in an efficient condition for furnishing an ample supply of clean oil.

Failure of Oil Supply. If the supply of oil to the bearings is interrupted, stop the turbine immediately; then take

the necessary steps to get the oil circulation reestablished. These steps may include any one, or a combination, of the following:

1. Clean the strainers.
2. Repair broken line.
3. Remove obstruction from line.
4. Put additional oil in the reservoir.
5. Increase the oil pressure by increasing the setting of the oil relief valve.

If a turbine has to be shut down because of an overheated bearing, it should be slowed down, but kept turning over at a low speed until the bearings and journal have cooled sufficiently to prevent the bearing metal from freezing to the shaft.

If it is noticed that the oil supply is failing, immediately examine the bearings, the lines, and the reservoir. If temporary repairs cannot be made satisfactorily with the turbine operating, the turbine must be secured.

OIL LEAKAGE. There are several causes for leakage and throwing of oil by turbines. The majority of these causes may be remedied by operating personnel. The following instances are cited with corrective measures to be taken:

1. If oil leakage occurs where a shaft emerges from a housing, the oil seals or deflector may be excessively worn or damaged. In such cases the oil seal or the deflector should be replaced.

2. The oil return holes may be too small or may become clogged with residue in the oil. As the bearings wear and the oil return holes become clogged with dirt, a greater quantity of oil than the holes can accommodate will pass through the bearings. This causes the oil to back up and out at the ends of the bearing. If the bearings are badly worn, the only remedy is to fit spare bearings. When the bearings are taken down for overhaul, the passage of the oil grooves and the oil return holes should be cleared of all sediment.

3. If the relief valve is set too high and oil leaks from the bearing ends, the pressure setting should be slightly reduced to allow some of the oil to be bypassed back into the reservoir.

## Care of Bearings

In general, repairs of bearings for propulsion turbines and ship's service turbogenerators are performed similarly.

Turbine bearings are split horizontally to facilitate installation and removal. They are generally of the babbitt-lined type, and the halves are prevented from rotating by means of dowel pins or setscrews. Make sure that the bearings are installed properly, receive sufficient lubrication, and do not become overheated. In addition, see that the bearing caps are maintained tight, in accordance with the manufacturer's instructions.

To remove a bearing lining, first remove the upper half of the bearing cap and the adjacent oil deflector. Remove the bolts which hold the two halves of the lining together, then lift off the upper half of the lining. Place the lifting yoke in position, and turn down the lifting yoke screw until the rotor is lifted sufficiently so that the lower half of the bearing lining may be rolled out.

Bearing lining halves are not interchangeable with those of another bearing; therefore, when requesting renewal parts, order both top and bottom halves of the bearing lining.

## Alignment of Turbine-Gear-Generator Sets

Successful operation of the turbine-generator set requires accurate alignment of the entire unit. Proper alignment of the unit requires the setting of the gear casing to maintain the centerlines of the reduction gear and pinion gear in the same plane. This is essential to obtain satisfactory tooth contact. For proper alignment it is also required that the pinion and turbine shafts (as well as the gear and generator shafts) run true with one another.

In addition, the centerline of the generator must be in the same vertical plane as the centerline of the turbine.

## Inspection of Governor Control Valves

When turbines are dismantled for repairs or inspection, the condition of the governor control valve should be checked.

Where governor valve seats are loose, they should be seal-welded or silver-soldered in place, if practicable. Inspection of the valve seats frequently discloses that seating areas are steam cut and eroded. Replacement valve seats should be ordered in accordance with manufacturer's specifications.

BuShips has received numerous reports of overspeeding and failure to parallel at light loads on turbogenerator sets (GE 500-kw to 1250-kw), due to excessive leakage between the control valve seats and the steam chest. In many cases, the leakage has been corrected by seal welding the existing valve seat inserts in the steam chest. The following procedures will minimize the danger inherent in a repair of this type and ensure uniformity of corrective action:

1. Insert suitable carbon, copper, cast iron, or wooden plugs in the valve seats to protect the seating surface from weld spatter or from other damage.

2. Seal-weld the valve seats to the steam chest, observing the following precautions:

a. The temperature of the metal parts should range from 150° F to 250° F, during welding.

b. A single layer bead weld should be made by using ⅛-inch diameter electrode conforming to Navy Specification 46E3(INT), grade III, class 1, at approximately 100 amp d-c straight polarity (electrode negative). The weld should be started at a suitable location on the periphery of the joint to be sealed so that the starting point can be overlapped approximately ½-inch before drawing the bead off the joint onto the steam chest floor for breaking the arc.

c. After one seat is welded, a period of approximately 15 minutes should be allowed for temperature equalization, before an adjacent seat is welded. Alternate seats may be welded without any time delay.

d. After the slag and weld spatter have been removed, all welds should be tested with magnetic powder and any defects properly repaired. The valve seat facing should then be visually inspected for cracks or other damage. Seats exhibiting cracked seat facings should be replaced with new seats.

e. After seal-welding has been completed, the valves and valve seats should be spotted in.

8. Check to see that there is a minimum of $\frac{1}{32}$-inch clearance between the ends of the lift rods and any weld on the seats, with the valves closed, after the valves are reassembled.

### Adjustment of Main Speed Governor

This governor is adjusted at the factory for a normal operating speed of 618 rpm. The factory adjustment is permanent and should not be changed. Damaged governors should be sent to the factory to be retested and repaired.

If it becomes necessary to readjust the governor-lever fulcrum, the speed range, or regulation, may be changed as desired by shifting the position of the fulcrum pin in the holes in the restoring lever. To increase the percent regulation, use the holes farthest away from the trunnion pin. However, if the governor is too narrow, instability and consequent hunting (a variation at constant load) may result. Do not decrease the percent regulation to such an extent that hunting results.

### Testing of Overspeed Trips and Emergency Governor

Overspeed trips are installed primarily for the protection of equipment. Extreme care must be exercised in testing and maintaining these trips. In addition to being tested by hand, overspeed trips in use should be tested each week by overspeeding the units, where practicable. The overspeed trips should also be tested prior to being put in service after an idle period of one week or longer.

Overspeed Trip Test. This test, as well as the speed-limiting or emergency governor test, is generally conducted under the supervision of the engineer officer, with a reliable man at the turbine throttle, and a man with a tachometer at the exposed end of the shaft. In performing the overspeed trip test, start the turbine and run it slowly until adequately warmed up. Then with the constant speed governor rendered inoperative, gradually increase the turbine speed until the tripping speed is reached. The trip should function when the speed is about 10 percent above the normal operat-

ing speed. If the overspeed trip fails to function at this speed, the operator at the throttle should trip the unit by hand. Necessary adjustments should be made and the test repeated until satisfactory performance is obtained. The result should be entered in the engineroom log.

SPEED-LIMITING GOVERNOR TEST. Once each quarter, and at such times as may be necessary, speed-limiting governors should be tested by speeding up the turbines, using the method described below, and the result entered in the engineroom log.

Start the turbine and run it slowly until it is adequately warmed up. Then open the throttle and gradually increase the speed, taking readings with a tachometer. As the turbine approaches full speed, observe the action of the governor; it should operate smoothly. When the governor has control, carefully open the throttle valve somewhat wider and see that the speed does not increase to more than 5 percent above the maximum operating speed. If the governor fails to function at the proper speed, necessary adjustments should be made in accordance with the manufacturer's instructions; these adjustments are generally accomplished by means of the adjustment nut which is used to change the tension of the external spring.

If a speed-limiting governor is dismantled for any reason, a test should be conducted to assure proper functioning of the governor before the unit is put back into service.

### Abnormal Vibration

As soon as abnormal vibration is evident, a thorough investigation should be made to determine the cause(s) of the trouble. If the trouble is not immediately remedied and defects are allowed to accumulate, bearing and packing clearances become excessive, with consequent loss of oil and steam. In addition, the bearings and packing are soon ruined and if the turbine is kept in operation, further trouble may result in complete disablement of the unit.

Vibration of a turbine may be caused by:

1. Loose or poorly lubricated bearings.
2. Worn thrust bearings.

3. Rubbing or binding parts.
4. Driven unit out of balance.
5. Driven unit out of alignment.
6. Loose or broken foundation bolts.
7. Turbine rotor out of balance.
8. Carbon packing clearances too small.
9. Bent shaft.

If a turbine vibrates to such an extent that an out-of-balance condition is suspected, the following steps should be taken:

1. Examine the bearings and renew if the clearance is excessive.

2. Examine and, if necessary, adjust or renew the thrust bearing.

3. Examine all parts for evidence of rubbing or binding.

4. See if the carbon packing clearances are satisfactory. If the clearances are too small and the speed kept constant, the vibration will become worse. Friction will cause the shaft to overheat, and start to show heating colors. Be sure that sufficient steam is being supplied to the gland. If necessary, refit the packing.

5. Check the alignment, including contact surfaces of the reduction gears.

6. Check the bolts in the shaft couplings.

7. Look for loose bolts in the unit and its support. Replace or tighten bolts, if necessary.

8. Remove the rotor and the shaft. If possible, check the shaft in the lathe, for runout.

9. After the above steps have been performed and the turbine is reassembled, run the unit at normal speed to determine if vibration has been eliminated.

If the turbine continues to vibrate, it probably is still out of balance and a running balance must be made. This may be accomplished in place by use of the Davey vibrometer carried by tenders and repair ships, or by removing the turbine and having it balanced at a naval shipyard. If the Davey vibrometer is used, maximum readings on the vibrometer scale should NOT exceed 0.003 inch.

## Lifting Turbine and Gear Casing

For lifting the turbine and gear casing of a turbine-generator set, BuShips authority is generally not required. The lifting procedures are the same as for main turbines and reduction gears.

DISASSEMBLY OF TURBINE AND ROTOR. The procedure to be followed in dismantling the turbine may be determined by studying the various illustrations and the unit itself. The following sequence and precautions are given only as a guide and in the expectation that they may prove helpful.

To remove the upper half of the turbine casing, proceed as follows:

1. Disconnect the oil and steam piping to the throttle valve.
2. Remove the throttle valve.
3. Disconnect the restoring lever from the controlling valves, and from the pilot valve and synchronizing device.
4. Remove the upper half of the turbine lagging.
5. Remove the bolts at the horizontal joint of the turbine high-pressure head and the exhaust casing. It is not necessary to remove the bolts from the circumferential joint.
6. Remove the upper halves of the high-pressure and low-pressure packing boxes. Lift vertically and carefully to avoid injury to the packing.
7. The casing may now be lifted. To aid in breaking the horizontal joint, insert some of the flange bolts in the blind tapped holes, on the horizontal flange of the upper-half wheel casing, and use them as jack screws. The upper halves of the diaphragms and diaphragm packing are fastened to the upper half of the casing and will be lifted with it.

To remove the turbine rotor, proceed as follows:

1. Remove the turbine bearing-bracket cap and the emergency tripping device.
2. Remove the packing rings from the lower halves of the high-pressure and low-pressure packing boxes.
3. Remove the pilot-valve housing from the gear casing.

Before removing the housing, see that the pilot-valve bushing is removed; otherwise injury to the pilot valve, to the bushing, or to both the pilot valve and the bushing, may result.

4. Remove the upper half of the gear casing.

5. Remove the top halves of the pinion bearings, and dismantle the thrust bearing.

6. Lift the turbine rotor and reduction-gear pinion as a single element.

Disassembly of Gear. The turbine governor and the pilot valve are mounted on the reduction gear. Therefore, when removing the upper half of the gear casing, it is necessary to proceed as follows:

1. Disconnect the restoring lever linkage, between the pilot valve and the control valve piston rod, and other parts that form a connection between the turbine high-pressure head and the upper-half gear casing. Care must be taken to avoid damage to the pilot valve.

2. Remove the thrust bearing cover and the two top studs that hold the high-speed thrust bearing to the upper-half gear casing.

3. Remove the bolts from the upper and lower half of the gear casing. Remove the end cover plates, which are bolted to the upper and lower casing. Remove the coupling guard from the upper-half and the joint bolts in the oil deflectors. Remove the taper dowels from the joint flange.

4. Remove all thermometers and gages from the upper-half gear casing.

5. Open the horizontal joint, between the upper and lower gear casing, by means of jacking bolts screwed down into the threaded holes provided in the flanges of the upper half of the casing.

6. Lift the casing by means of the eyebolts provided, taking care not to let the casing strike against the gear. Since the pilot valve remains connected to the governor, be sure to lift the casing high enough to let the pilot valve clear.

The pilot valve body may, if necessary, be removed from the gear casing by removing the studs at the flange connections.

## ROUTINE INSPECTIONS

The following routine inspections should be performed while the ship is under way:

| When made | Part of system | Purpose |
|---|---|---|
| (a) At very short intervals during each watch | Bearings | To detect signs of overheating. |
| (b) At very short intervals during each watch | Flow of oil made through sight glasses | To check flow of oil. |
| (c) At very short intervals during each watch | Rotor position indicator on generator sets | To check axial position of rotor. |
| (d) At very short intervals during each watch | All gages | To check pressures. |
| (e) Once a watch | Ball thrust bearing and radial bearings | To detect defects in or damage to bearings. |
| (f) Once a watch | Operate speed-limiting or speed-regulating valve stem manually. | To ensure proper functioning. Caution: Do not overspeed unit. |
| (g) Daily | Parts under vacuum | To detect air leaks. |

The following routine inspections should be carried out while the ship is at anchor, and appropriate entries made in the log:

| When made | Part of installation | Purpose |
|---|---|---|
| (a) Daily | Turn idle turbines by hand and circulate oil by hand pump, if provided. | To prevent freezing. |
| (b) Weekly | Valves, cocks, joints of steam, exhaust and drain lines | To check tightness. |
| (c) Weekly | Operate and oil the regulating valves and throttle valves | To prevent sticking. |
| (d) Weekly | Operate and oil, if possible, all valves not used | To prevent freezing of parts. |
| (e) Weekly | Lubricate the overspeed trip mechanism, if installed | To prevent sticking. |
| (f) Weekly | Run the turbine with steam if practicable | To assure that turbine will be ready on short notice. |
| (g) Weekly | Test the overspeed trip, if installed, by overspeeding the unit. | To prevent freezing of parts. |

| | | |
|---|---|---|
| (*h*) Weekly | Operate relief valves by hand | To prevent sticking. |
| (*i*) Quarterly | Test speed-limiting governor. (This shall also be done each time a turbine is put in operation after having been permanently secured.) | To see that governor functions at speeds for which set. |
| (*j*) Quarterly | Examine casing interior through peep holes where design permits. | To see that rotor and nozzles are in line. |
| (*k*) Quarterly | Sound the casing with a hammer | To detect cracks. |
| (*l*) Quarterly | Examine for loose or broken bolts, inspect turbine casing exterior for corrosion. | To detect signs of loosening of turbine fastening and to detect corrosion. |
| (*m*) Quarterly | Test relief valve by steam | To check proper setting. |
| (*n*) Quarterly | Clean the steam strainers (clean oftener if extensive cruising has been done). | To prevent foreign matter from entering turbine and to ensure integrity of the strainers. |
| (*o*) Quarterly | Shoes of thrust for clearance and condition of bearing surface. | To ensure proper position of rotor. |
| (*p*) Quarterly | Blow out thrust with air after examination | To prevent foreign matter remaining. |
| (*q*) Quarterly | Sleeve bearings for clearance, condition of journal and bearing surfaces. | To ensure that radial clearance is correct. |
| (*r*) Quarterly | Calibrate gages | To ensure correct readings. |
| (*s*) Biannually | Gland packing for wear | To ensure maintenance of efficient seal. |
| (*t*) Biannually | Open up and examine all ball bearings and radial bearings | For examination and cleaning. |
| (*u*) When first starting turbine (cold) | Rotor position indicator on generator turbines | To check axial clearances. |
| (*v*) When first starting turbine (hot) | Rotor position indicator on generator turbines | To check axial clearances. |

## Repair Guide List

**A sample repair guide list which should be followed in the overhaul of a turbine is given below:**

**No.**.................................................**Turbine**
**Type**.................................................
**Manufacturer**.................................................
**Size**.................................................
**Date**.................................................

| Overhaul and Repair Procedures | Standard | Present bridge gage reading or crown thickness | Last bridge gage reading or crown thickness | Amount of wear | Done | Not done |
|---|---|---|---|---|---|---|
| 1. Assemble drawings | | | | | | |
| 2. Collect previous data | | | | | | |
| 3. Sleeve bearings | | | | | | |
| (*a*). Take bridge gage or crown thickness reading | | | | | | |
| Turbine bearing, for'd | | | | | | |
| Turbine bearing, aft | | | | | | |
| Pinion bearing, for'd | | | | | | |
| Pinion bearing, aft | | | | | | |
| Gear bearing, for'd | | | | | | |
| Gear bearing, aft | | | | | | |
| (*b*) Inspect, clean, rebabbitt or renew | | | | | | |
| (*c*) Clean and dress journal | | | | | | |
| (*d*) Clean oil wells, passages, pockets, etc | | | | | | |
| (*e*) Reassemble | | | | | | |
| 4. Thrust bearing: | | | | | | |
| (*a*) Inspect, clean, renew parts: | | | | | | |
| (1) Ball bearings | | | | | | |
| (2) Collar | | | | | | |
| (3) Shoes or thrust plates | | | | | | |
| (*b*) Adjust for proper clearance | | | | | | |

| Overhaul and Repair Procedures | Done | Not done |
|---|---|---|
| 5. Turbine valves: | | |
| (*a*) Examine | | |
| (*b*) Adjust | | |
| (*c*) Grind in seat | | |
| (*d*) Grind in disk | | |
| (*e*) Test | | |
| 6. Fittings: | | |
| (*a*) Inspect, clean, and adjust: | | |
| (1) Relief valve | | |
| (2) Speed-limiting or constant-speed governor | | |
| (3) Overspeed trip | | |
| (4) Low-oil pressure alarm contactor or trip | | |
| (5) Back pressure trip | | |
| (6) Gages | | |
| 7. Packing: | | |
| (*a*) Examine for defective segments or rings | | |
| (*b*) Clean all parts | | |
| (*c*) Replace defective parts | | |
| (*d*) Adjust and reassemble | | |
| 8. Rotor: | | |
| (*a*) Inspect: | | |
| (1) Blade wheels | | |
| (2) Keys for blade wheels | | |
| (3) Wheel securing nuts | | |
| (4) Blades | | |
| (5) Shrouding | | |
| (6) Packing sleeves | | |
| (7) Forward journal | | |
| (8) After journal | | |
| (*b*) Clean all parts | | |
| (*c*) Straighten blades | | |
| (*d*) Clean, polish, straighten shaft | | |
| (*e*) Measure and record axial clearances | | |
| (*f*) Adjust axial clearance | | |
| 9. Casing: | | |
| (*a*) Inspect and clean as necessary: | | |
| (1) Interior surface of casing | | |
| (2) Nozzle | | |
| (3) Nozzle diaphragms | | |
| (4) Diaphragm packing rings | | |

| Overhaul and Repair Procedures | Done | Not done |
|---|---|---|
| 9. Casing—Continued | | |
| (*a*) Inspect and clean as necessary—Continued | | |
| (5) Axial crushing pins | ---- | ---- |
| (6) Radial crushing pins | ---- | ---- |
| (*b*) Examine for loose nozzle bolts or nuts and tighten if found | ---- | ---- |
| (*c*) Clear all drain holes | ---- | ---- |
| 10. Oil system: | | |
| (*a*) Inspect, clean, adjust: | | |
| (1) Lines | ---- | ---- |
| (2) Reservoir | ---- | ---- |
| (3) Strainer | ---- | ---- |
| (4) Oil pump | ---- | ---- |
| (5) Oil gage | ---- | ---- |
| (6) Hydraulic cylinders | ---- | ---- |
| (7) Oil cooler | ---- | ---- |
| (*b*) Flush with approved compound | ---- | ---- |
| (*c*) Flush with oil | ---- | ---- |
| (*d*) Refill with clean oil | ---- | ---- |
| 11. Replacing casing: | | |
| (*a*) Clean flanges, bolt holes, etc | ---- | ---- |
| (*b*) Clean grooves | ---- | ---- |
| (*c*) Polish flanges | ---- | ---- |
| (*d*) Examine casing for articles left behind (tools, waste, metal, etc.) | ---- | ---- |
| (*e*) Blow through with air | ---- | ---- |
| (*f*) Apply jointing material | ---- | ---- |
| (*g*) Lower cover | ---- | ---- |
| (*h*) Replace bolts and set up on nuts | ---- | ---- |
| 12. Reduction gears: | | |
| (*a*) Thoroughly clean by blowing with air: | | |
| (1) All oil passages in the casing | ---- | ---- |
| (2) Oil pipes | ---- | ---- |
| (3) Oil manifolds | ---- | ---- |
| (4) Spray nozzles | ---- | ---- |
| (*b*) Examine pinions and gears for: | | |
| (1) Damaged teeth | ---- | ---- |
| (2) Pitting | ---- | ---- |
| (3) Rusting | ---- | ---- |
| (*c*) Remove any burrs from pinion or gear with a fine file or oil stone | ---- | ---- |

| Overhaul and Repair Procedures | Done | Not done |
|---|---|---|
| 12. Reduction gears—Continued | | |
| (*d*) Check alignment and clearances | ---- | ---- |
| (*e*) Clean oil joints of casing | ---- | ---- |
| (*f*) See that no material is left in gear case | ---- | ---- |
| (*g*) Replace covers | ---- | ---- |
| 13. Reassemble: | | |
| (*a*) Check alignment of turbine and driven apparatus | ---- | ---- |
| (*b*) Check alignment of rotating blades and stationary blades or reversing chambers | ---- | ---- |
| 14. Test: | | |
| (*a*) Turn over by hand | ---- | ---- |
| (*b*) Turn over with steam | ---- | ---- |
| (*c*) Test overspeed trip or speed-limiting governor | ---- | ---- |

## SAFETY PRECAUTIONS

The following safety precautions should be observed:

1. Turn the turbine daily by hand and before admitting steam to the casing.

2. Do not lash down an overspeed trip or a speed-limiting governor, nor take other steps to render them inoperative.

3. Keep the exhaust casing relief valve set at the proper pressure and in operating condition at all times. Test by hand before admitting steam to the casing, and test quarterly by steam, gradually closing the exhaust valve (if fitted) until the relief valve lifts. During this test, an exhaust pressure gage must be carefully watched.

4. Keep the oil reservoir well filled with clean oil at all times.

5. Inspect the turbine, before starting, especially if the unit has not been operated for a long period, to see that no foreign matter is present.

6. Keep the unit properly balanced at all times.

7. Avoid water hammer by properly draining lines and opening valves slowly.

8. Test the overspeed trip (if provided) before the turbine is put in service.

9. Test the speed-limiting governor by steam at least once each quarter.

10. Prevent steam from passing through a turbine with the rotor at rest.

11. Prevent air from entering the generator turbine glands.

12. Keep the governor operating mechanism and regulating valve stems clean and free from corrosion, and the cylinder insulation well clear of the steam-chest lift rods.

13. Keep the bearing oil pressure at the proper amount.

14. Keep the oil strainer clean.

15. Keep the oil cooler clean.

## SUMMARY

As an MM 1 or C, you should become familiar with the methods and procedures for starting and securing steam turbine generators. In addition, it will be your responsibility to see that routine tests and inspections are performed, and that the necessary authorized adjustments and repairs are made.

Every possible means should be used to maintain the oil in a clean condition. If the oil supply fails, the bearings, the lines, and the reservoir must be examined immediately. If temporary repairs are impracticable, the turbine must be secured. Most troubles resulting from leakage and throwing of oil by turbines can be corrected by operating personnel.

Freedom from vibration is essential to the operation of turbines. As soon as abnormal vibration is noted, a thorough investigation should be made to determine the cause(s) of the trouble.

In dismantling the turbine, the procedure to follow may be determined by studying the instructions for the various installations, as well as for the individual unit.

## QUIZ

1. What is the function of the centrifugal governor of a typical ship's service generator turbine control mechanism?
2. When will the governor weights of the speed control mechanism move inward and result in an upward motion of the pilot valve?
3. When a turbogenerator is being started, why should a reasonable amount of time be spent in warming up the unit?
4. The maximum temperature of the bearings in an operating turbine should not exceed how many degrees?
5. Why must extra precaution be taken when a turbogenerator is shut down, even for a short time?
6. How often should the turbine unit and foundation be carefully inspected for loose and broken nuts and bolts?
7. When must the oil in the reservoir be renewed or renovated frequently?
8. What should be done if a turbine has to be shut down because of an overheated bearing?
9. If the oil supply of a turbogenerator is failing, what should be examined immediately?
10. When governor valve seats are loose, what should be done, if practicable?
11. After one governor valve seat is welded, approximately how much time should be allowed for the temperature equalization, before an adjacent seat is welded?
12. What should be done with damaged speed governors?
13. If a speed-limiting governor is dismantled for any reason, what should be done before placing the unit back into service?
14. If abnormal vibration is noted, what should be done immediately?
15. How can the procedure used to dismantle a turbine be determined?
16. What should be done before removing the pilot-valve housing from the gear casing?
17. When a ship is under way, how often should a routine inspection be made of all parts under vacuum?
18. How often should the valves, cocks, and drain lines be checked for tightness?
19. How often should the speed-limiting governor be tested to see that it functions at speeds for which it is set?
20. How often should a turbogenerator be turned manually?

# CHAPTER 6

# PUMPS

This chapter emphasizes the types of inspections and the repair and overhaul procedures commonly required for reciprocating and centrifugal pumps. A section on the operation and repair of pressure-regulating governors is also included.

Pumps are the most numerous units of auxiliary machinery aboard ship; therefore, care and maintenance is an extremely important task. Faulty operation or maintenance, improper lubrication, and neglect to observe safety precautions are the major causes for pump failure. As an MM1 or C, you will be responsible for adjustments, maintenance, trouble shooting, and operational repair of all pumps in the engineroom and other assigned spaces.

## RECIPROCATING PUMPS

### Maintenance

In order to maintain reciprocating pumps properly, periodic tests and inspections must be made. Two important maintenance factors are adjustment of piston stroke and alignment of pumps.

ADJUSTMENT OF STROKE. In order for a reciprocating pump to operate properly, the piston should travel a little beyond counterbore; this means that the pump must operate with the full length of stroke. A full stroke ensures a more even wear throughout the cylinder.

When a pump does not have full stroke, something is wrong with the adjustment. A short stroke results in incomplete cushioning and the formation of shoulders in the cylinders and valve chests, with resultant breakage of rings and followers. These shoulders will have to be removed before full stroke can be obtained. Long stroke is usually indicated by a heavy metallic knock in the steam cylinder and should be immediately corrected.

To shorten the stroke of the pump, turn the tappet collar in one direction; to lengthen the stroke, turn the collar in the opposite direction. Once the tappet collars have been set, they should be left alone. However, if it becomes necessary to adjust the tappet collars at frequent intervals while the pump is operating, the pump should be shut down and dismantled as soon as possible, and the interior parts examined.

Properly adjusted cushioning valves will ensure a full stroke for the various pump loads and speeds. The following is a satisfactory rule of thumb for setting steam valves. Place pistons and valves in the centers of the cylinders, or on half stroke. Then with the top collar all the way down to the tappet, the auxiliary valve should be open $\frac{1}{4}$ inch at the top; and with the bottom collar all the way up to the tappet, the auxiliary valve should be open $\frac{1}{4}$ inch at the bottom. With the collars at equal distances from the tappets, the auxiliary valve should be at the center.

Another method for setting valves is to place the piston and the auxiliary valve on the center, then move each collar from the tappet $\frac{1}{2}$ the width of the steam port. If the tappet moves the full distance of the stroke, the distance from the collar to the tappet will be $\frac{1}{2}$ stroke (steam port opening).

At times the steam valves of a duplex pump will have to be adjusted. The pump must first be drained of water. Place one piston on its top striking point, and after removing the steam chest cover of the valve chest of the other piston, adjust and tighten the valve so that there is an excess of $\frac{1}{8}$ inch full port opening at the bottom end. Then place

the piston on its bottom striking point, and adjust and tighten the valve of the other piston so that there is an excess of 1/8 inch full port at the top end.

The other valve can then be adjusted by going through the same procedure with the other piston.

To test whether the adjustment is satisfactory, crack the throttle and run the pump slowly, against little or no pressure, and with the cushioning valves wide open. If the cushioning valves are properly adjusted, the piston should make a complete stroke without striking the cylinder head. If the pistons do not make a complete stroke after the adjustment has been made, a tight piston rod and plunger packing may be causing binding. Determine the cause of the trouble immediately.

In figure 6-1 the piston and pilot valves are shown at the beginning of the up stroke. Both valves are in the upper position, thereby admitting high-pressure steam through the lower steam inlet port to the under side of the piston, and permitting steam above the piston to escape through the exhaust port.

When the piston reaches the top of the stroke the lever and tappet linkage move the pilot, or auxiliary piston valve, down, opening Port A to the annular exhaust space above the center of the auxiliary and main piston valves. Opening Port A thereby releases pressure in space B, below the piston valve, and permits the unbalanced higher pressure in space C to force the main piston valve down. The small size of the equalizing port in the piston valve prevents the escape of any appreciable amount of high-pressure steam into space B. The pilot valve has blanked off the upper port, preventing the escape of high-pressure steam from space C—even after the downward movement of the piston valve has uncovered that port—and thereby ensuring complete movement of that valve to its lower position.

At the end of its travel the piston valve cushions itself when it blanks off the port to space A, trapping dead steam which cannot rapidly escape through the small equalizing port in the valve. The initial condition of steam balance is

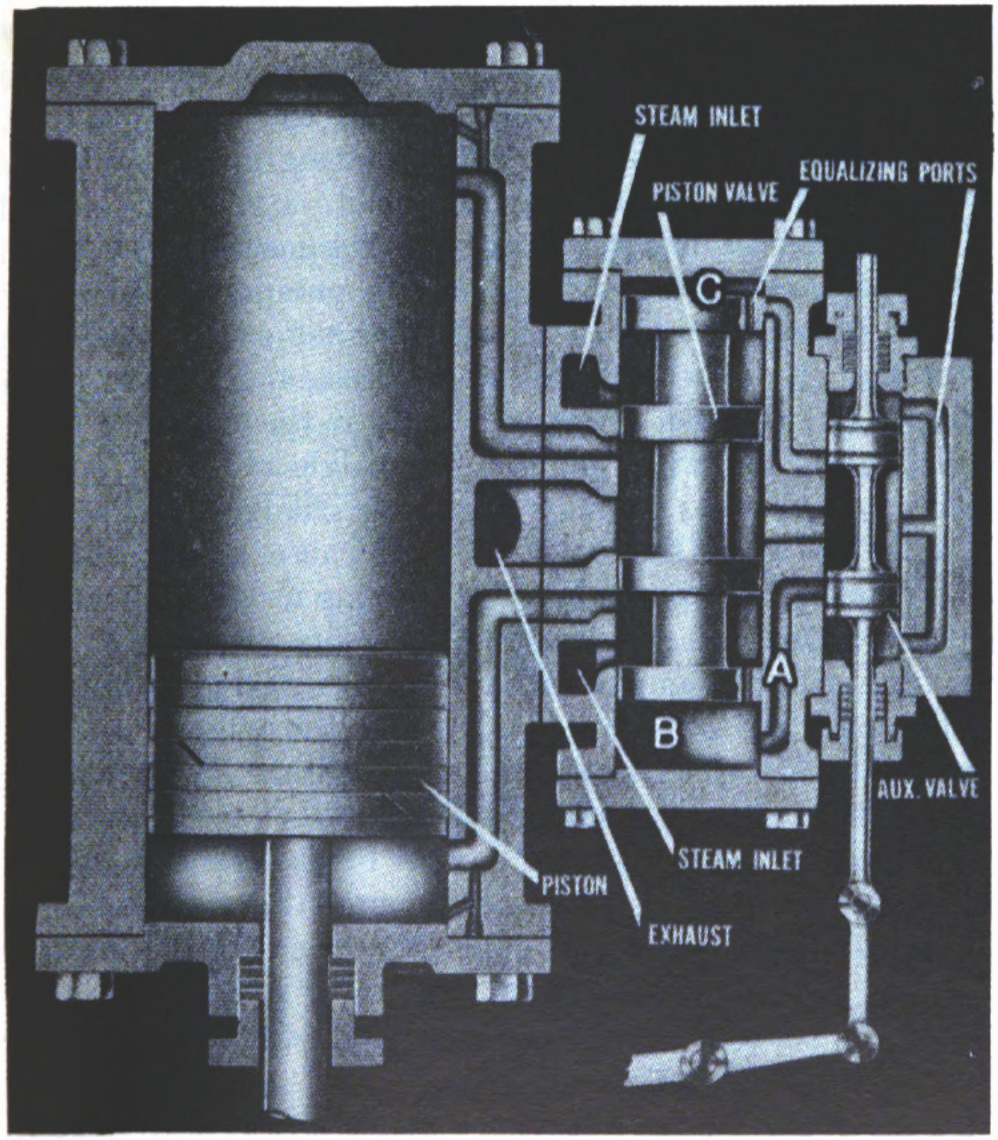


**Figure 6–1.—Piston slide valve.**

reestablished by means of this equalizing port. The above described movements are repeated on the opposite end of the stroke.

The force that actuates the main valve is determined by the difference in the rate of flow of steam through Port A, which is ¼ inch in diameter, and through the $\frac{1}{16}$-inch equalizing port drilled through the outside tappet collars of the main piston valve. Except when the main valve is actually in motion, it is in complete balance, both axially and circumferentially, so that the friction between the sliding surfaces is

the only force restricting its travel. The equalizing port, which connects the outer ends of the auxiliary valve cylinder, is essential to permit free movement of this valve. Light packing will suffice for the valve-actuating rod, since only auxiliary exhaust pressures must be held.

ALIGNMENT OF PUMPS. Improper alignment is one of the most frequent sources of trouble with pumps aboard ship. Pumps secured to a bulkhead are more subject to misalignment than those with independent bases and settings. A pump may have been properly aligned in the shop and then pulled out of line when bolted to the bulkhead; or, after the pump was secured, the ship may have changed shape sufficiently to warp the bulkhead and cause misalignment. Operation of an improperly aligned pump usually scores the rod and cylinders, and breaks the followers and bolts. Test the alignment of pumps occasionally by removing the piston and plunger and running a line through the cylinders. This should be performed as a routine test within the first year after a ship is commissioned; and also in the case of a pump that is scoring the rod or cylinders, or breaking followers.

Sometimes, when steam cylinder foundation pad bolts are slacked off, the cylinder pad pulls away from the foundation as much as ½ inch, indicating settling of foundations and bulkheads. Correct this by fitting shims between the foundation and the pump.

Before a line is run through the cylinder or any adjustments are made, the foundation must be lined up and you must determine the location of the centerline. The centerline must divide the cylinder equally. (See fig. 6–2.) Fasten one end of the line to a temporary beam at the end of one of the cylinders. In figure 6–2, the temporary beam is rigged above the steam cylinder. Run the line down the center of both cylinders, and center it at the bottom and top of the steam cylinder, so that it becomes the axis of the cylinder.

Then align the water cylinder with the steam cylinder. The water cylinder may be moved and centered on the line

without affecting the centering of the line on the steam cylinder.

To make a rough check of alignment of a pump, pull the steam and liquid end rod packing, and check the clearances between the piston rods and the cylinder head throat bushings. Make this check with the pistons in three positions—top, center, and bottom of the stroke. If clearance is not uniform, but the throat bushings are not worn out of round, realign the pump as soon as practicable.

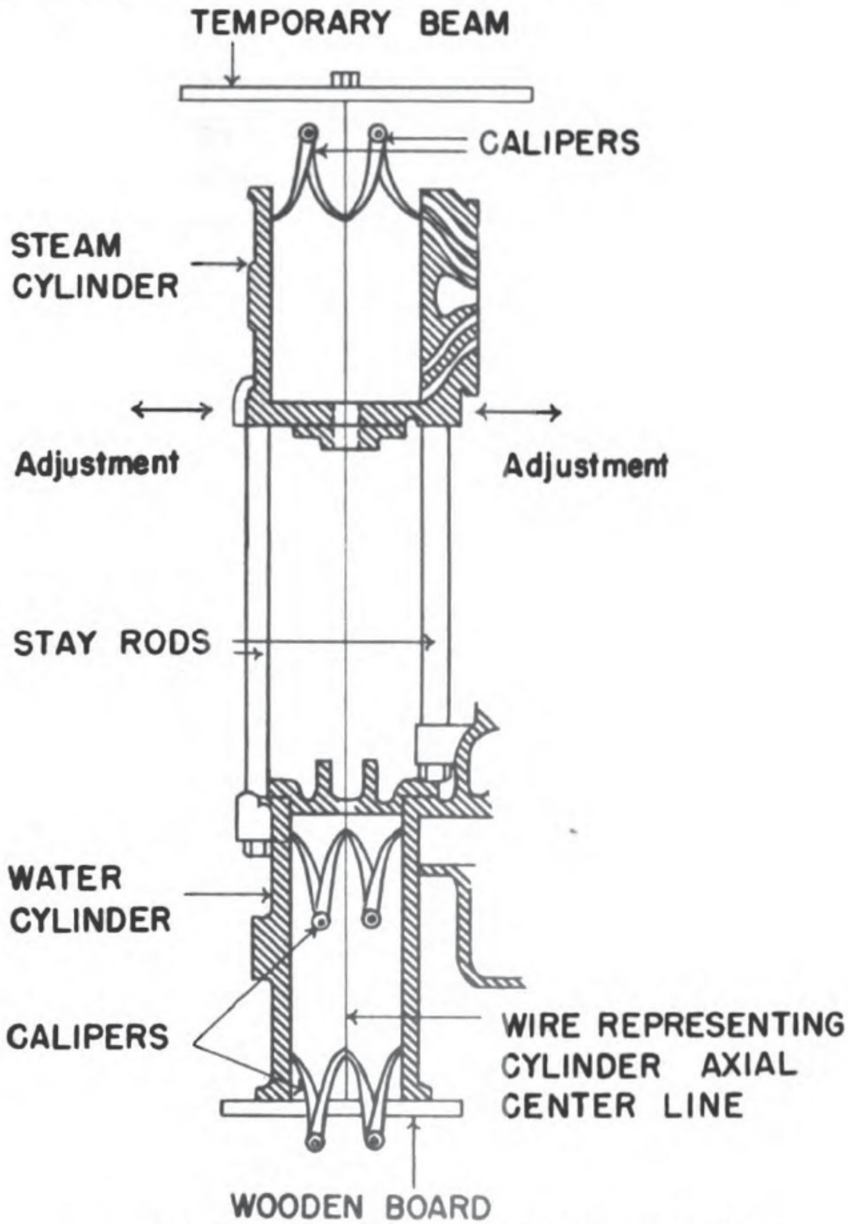


**Figure 6–2.—Centering a line through two cylinders.**

Misalignment may also result if the connection between the pump and foundation allows for no expansion. This condition can be corrected by lengthening the foundation bolt holes in the steam cylinder foundation pad, or by using foundation bolts $\frac{1}{8}$ inch smaller in diameter than the holes.

## Troubles and Remedies

FAILURE TO START. If a reciprocating pump fails to start, proceed as follows:

1. Secure the pump. Do not attempt to adjust the tappet collars.
2. Examine the discharge and exhaust line for closed valves, or for a valve disk that has become detached from its stem. If no valves are closed, the plunger or steam piston may be frozen, particularly if the pump has not been in service for some time.
3. Jack the pump with a bar, if the pump has been idle for some time, to determine if there is excessive friction.
4. Disconnect the auxiliary valve stem from the operating gear, without adjusting the tappet collars. Open the exhaust, suction, and discharge valves, and then crack the throttle. Work the auxiliary valve by hand (it should work freely if the packing is not seizing the stem).
5. If the pump still fails to start, secure it. Remove the steam valve chest cover and examine the main piston valve to see if it has overridden or stuck.
6. If the pump cannot be started, completely overhaul the working parts of the steam end to stop steam leakage, the most probable cause of the trouble.

FAILURE TO TAKE SUCTION. If the pump fails to take suction, the operation will be jerky. To correct this, proceed as follows:

1. See that all stop and check valves in the suction line are open, and that the line is free of obstructions.
2. If the feed pump is vapor-bound, take a suction from the reserve feed tank with the standby pump. Open the cylinder vents on the vapor-bound pump and allow it to

cool. If no standby feed is provided, open the cylinder vents, shift the suction to the reserve feed tank, and turn a water hose on the water end of the pump. If suction is not picked up, follow the low-water procedure. (See chapter 8 of this training course.)

3. If the pump has a suction lift (as a bilge pump), it may be necessary to prime the pump before it will take suction. Salt-water pumps can usually be primed from the sea by opening the sea suction valve for a short interval.

LOSS OF DISCHARGE PRESSURE. When a pump loses discharge pressure, the trouble is usually due to a leaky plunger; to a leaky, broken, or stuck valve in the water end; or to air being admitted through open or leaky valves in the suction line. Stop the pump as soon as practicable, and trace and correct the trouble. If a pump has been operating properly and loses pressure on one stroke, look for a broken valve immediately. Great loss of efficiency results from leaky suction and discharge valves, and from leaky plungers.

POUNDING IN THE WATER END. The remedy for this is to (1) slow down the pump, since pounding is usually due to water hammer or ram effect in the suction piping, (2) examine the plunger, or the plunger rod where it is secured in the crosshead, for lost motion, and look for a loose nest of valves, (3) install heavier springs in the suction valves, and (4) if an air chamber is installed on the suction side, see that it remains charged.

GROANING IN THE WATER END. This is usually due to the packing being too tight, but may be caused by a broken follower plate or by another part. Stop the pump and examine it at once, as failure to do this may result in the scored cylinder.

KNOCKING IN THE STEAM CYLINDER. This is indicative of loose piston rings, a loose piston on the rod, or some maladjustment of the valve mechanism. The pump should be stopped at once and the exact trouble rectified.

GROANING IN THE STEAM CYLINDER. This is usually due to an excessive ring pressure against the cylinder walls, to

broken piston rings, or to the cylinders being out of alignment. Rust may cause groaning when a pump is started after a long period of idleness.

## Repair and Overhaul of Reciprocating Pumps

When repairs are undertaken, a repair guide list should be used to make sure that every part of the pump which required attention or contributed in any way to poor performance is put in proper condition. Such a guide list should be used even for partial or incomplete overhaul. When a partial overhaul only is undertaken, check NOT DONE for each item listed on which no work is done. This shows that the part has been inspected, or at least considered, and work found impracticable or unnecessary. Upon completion of work, preserve the repair guide list as a record of conditions found, data taken, and work accomplished. Repair guide lists in sufficient numbers should be available for use when the next overhaul is started.

For repairing or making an interior examination of a pump, all drawings and available dimensional data relative thereto should be on hand. If dimensions such as the width of and the distance between steam ports, the length of rods and steam valves, and the diameter of the pistons are not in accordance with authorized specifications, poor operation will result and necessitate major repairs.

Whenever pumps are opened for repairs, micrometer or caliper measurements should be taken of the cylinders and valve chests; these measurements are made on the fore and aft and athwartships diameters at the top, middle, and bottom. The results should be recorded on the Machinery History Card, with an accompanying diagrammetric sketch showing measurements obtained and the date on which they were made.

SCORED WATER CYLINDER. When a water cylinder becomes scored, it is not always necessary to rebore or renew the liner. Slight leakage from wear can be corrected by stoning the cylinder liner and by adjusting the packing. If reboring

must be done, the tolerances in wear of the water cylinder should be checked; tolerances allowed in boring the cylinder are tabulated in chapter 40 of BuShips *Manual*.

SCORES IN STEAM CYLINDER. Scoring in a steam cylinder, even though of a minor nature, necessitates reboring to prevent steam leakage past the piston. The presence of such leakage is indicated by a dullness and discoloration of the cylinder walls. Once leakage has started, steam will gradually cut away cylinder walls until piston leakage becomes so excessive as to interfere with proper operation of the pump.

LOOSE PISTONS. Pistons at the water end of pumps are generally constructed of cast iron, and are of the body and follower type. The piston itself is not a tight fit, but depends upon several rings of fibrous packing to prevent leakage. These rings of packing are placed between a shoulder at one end of the piston and a follower at the other end. A water piston is shown in figure 6–3.

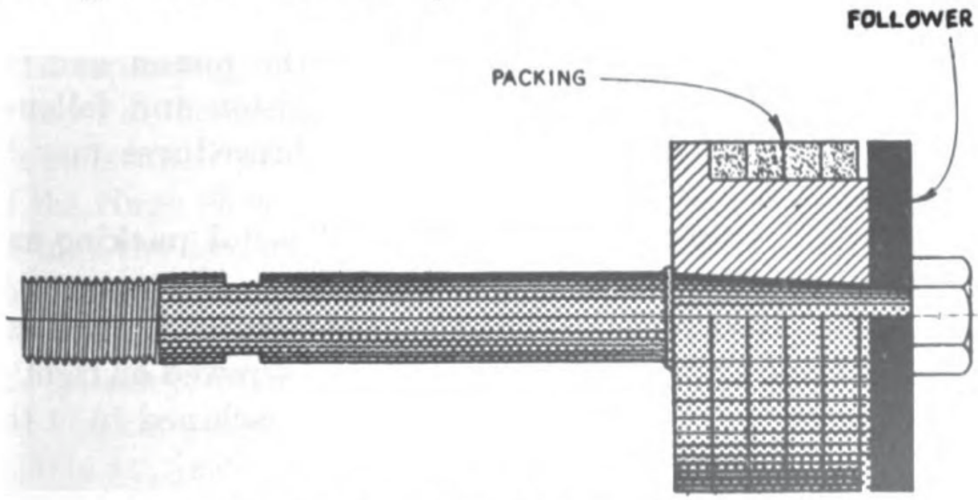


**Figure 6–3.—Water piston with divided piston rod.**

If a steam or water piston works loose on the rod, it is generally due to poor workmanship and assembly or to the rod being so fitted that the shoulder bears against the piston without giving a proper bearing surface for the tapered part of the rod. When set up handtight, the piston should fit within $1/32$ of an inch of the shoulder; it should then be forced tightly against the shoulder by the securing nut. However, the piston cannot be brought firmly home unless all foreign

matter has been removed from the taper of the rod. Piston trouble will usually disappear when the piston is properly refitted to the rod.

If a lock nut or split pin is not fitted, install one. Pump rods are sometimes screwed into the plunger and secured by a lock nut, with a flat plate secured on the top of the plunger to prevent the nut from backing off. However, this arrangement will still allow the nut and the plunger to turn together, permitting the plunger to back off and carry away. To correct this condition, drill a hole half in the rod and half in the nut, and tap; then insert a headless stud, or setscrew, into the hole and drive it home. A copper washer under the nut will help secure the nut from turning and working loose on the rod.

Piston Too Small. Pistons may be built up by flowing on metal by the oxyacetylene method or by electric welding. The piston is then machined to the proper fit.

It sometimes happens that in reboring a water cylinder you introduce so much clearance that the piston and the follower require renewal. Until a new piston and follower can be obtained, one of the following procedures may be employed:

1. Install upper and lower rings of metal packing and insert soft packing between the rings.
2. The piston and the follower may be turned down and threaded, and a ring with the same thread screwed on tightly. The outside diameter of the ring is then machined to fit the cylinder.

If the pistons are so much undersized that the above procedures are not satisfactory, the pistons may be built up by flowing on metal, and then turned to the correct diameter.

Breaking of Followers. The breaking of followers and bolts may result from misalignment, but is generally caused by a weak follower. A new and heavier follower, or one of better material, should be tried on a pump to see if it stops the trouble. The breaking of followers can be prevented by drilling the piston for through bolts for securing the follower.

When the follower is too small in diameter, soft packing

will frequently roll up between the piston and the cylinder, causing the follower to jam and break.

Renewing Packing. Tuck's flax or other soft packing should be soaked in water overnight before being used to pack the pump. Should circumstances make soaking impracticable, install the packing so that it fits loosely and makes allowance for swelling. Failure to do this will cause the pump to groan, or may result in a scored cylinder.

Worn or Broken Piston Rings. Troubles in the steam cylinder result chiefly from faulty piston rings. Wearing of piston rings can cause a pump to lose power, and even, in some cases, to stop.

To remove the piston rings, it is necessary to first remove the cylinder head and pull the piston from the cylinder. When the rings have been removed, take micrometer measurements of the cylinder or liner, to determine the exact diameter. In addition, measure the ring grooves in the piston to determine the thickness of the new rings.

In replacing broken or worn rings, first fit them to the cylinder and check for proper gap clearance. If necessary, file the ends until proper clearance is obtained. The thickness of the rings should be checked, to make sure that they will fit into the grooves. The ring gaps must be staggered so that they do not fall in one line.

With split rings, the steam may force the rings out against the cylinder, causing the pump to groan, and to cut the cylinder and the rings. The remedy is to turn a groove approximately $\frac{1}{32}$-inch deep and $\frac{3}{8}$-inch wide about the middle of the ring and drill three or four $\frac{1}{8}$-inch holes. This will relieve the steam pressure through the ring. Diagonally cut split rings generally give better satisfaction than overlapping rings; the latter usually break at the corner after being in service a short time. However, this trouble can be reduced by rounding the corners of the shoulders.

If no spare rings are available, new ones can be manufactured in the ship's machine shop. In this event, make certain that the cylinder micrometer reading appears on the job order

request. For renewing cylinder rings, the following procedure is recommended.

The ring should be turned, before splitting, to 0.10 of an inch per inch of diameter larger than that of the steam cylinder in which it is to be fitted. This is done so that the ring will be under tension, and even after slight wear will remain in close contact with the cylinder wall, minimizing leakage. Then the ring should be cut and an amount taken out which is approximately twice the difference between the diameter of the rough turned ring and the diameter of the bore of the cylinder. A liner, consisting of a piece of chart paper (use thinner paper for the smaller size pumps) is now placed in the gap made by splitting. The ring is secured on the face plate of a lathe and turned to the exact diameter.

Valves in Water End. All valves in the water end of the pump must be kept tight to ensure satisfactory and economical pump operation. Valves may be faced in a lathe and then ground in on their seats by a simple device which consists of a length of rod slotted to fit a piece of metal which seats across the top of the valve. An ordinary bitstock can be used to do the grinding.

It is sometimes desirable to take a cut off the valve seat without removing it. A simple cutter can be made with an extension for a bitstock similar to the grinding-in device. When flat valves are fitted, the seats may be trued up by using a small surface plate and spotting in the section on the surface plate.

After the valves have been ground in, test the whole pump by closing the discharge valve, starting the pump, and checking the proper suction and discharge pressure.

At each examination, try all metal valve disks with a straightedge to see if they are true. The life of rubber valves can be lengthened by trimming and turning valves and by inserting brass backings.

Tension on the valve springs should be great enough to ensure a quick closing of the valve, but not so great that the valve cannot be lifted easily by hand. See that the

springs are well secured by split pins, and adjust the valves to give the proper fit. Lift should be such that the circumferential opening is slightly greater than the clear opening through the seat, but NOT greater than ¼ of the diameter of the opening.

Keep the valves clean; a light mineral oil makes a good cleanser and a lye or soda solution is satisfactory for removing caked or gummed oil from the valves.

In pumps having valve seats secured only by a taper fit, the seats should be forced home by a jack resting on the end of a reseater which, in turn, rests on the face of the valve seat. If the seat works loose, peen the edge of the metal slightly. In pumps that have the valve seats screwed into the pump diaphragm, always insert the valve seats with white lead; otherwise it will be almost impossible to get them out.

In some pumps, discharge valve seats in the water end are secured to the pump diaphragm by shoulders on the valve stems where they screw into the suction seats. These seats have small flanges under which gaskets are fitted. Rubber gaskets supplied by the manufacturer are soon squeezed out, causing the seats to leak and hammer. Hard sheet packing will give better performance than rubber, and if cold water is to be pumped, sheet lead will give the best performance. In cases where the flanges cause a great deal of trouble, it will be necessary to fit new seats with a ground joint.

Shearing off the stems of water-end valves is a frequent occurrence. To remedy this fault, cut the stem off the valve and turn a groove in the top of the valve for the spring to set in. The stem is pinned to the guard at a sufficient height to allow proper opening of the valve; it then acts merely as a guide for the spring and as a limiting device for the valve. It will be necessary to fit a new stem because the old one will not be large enough to make a close fit in the guard.

Extreme care should be exercised in assembling pumps after overhaul. Mark valves, seats, stems, and springs before removal, to make it easier to replace them in the proper order.

# MAIN CONDENSATE AND MAIN BOOSTER PUMPS

The instructions contained in this chapter for operation, care, and repair of pumps are general for all makes and types. For specific instructions for each type of pump, refer to the pamphlets issued by the individual manufacturers.

## Operation of Feed Booster and Condensate Pumps

Before a feed booster pump is started, the valves in the vent line, recirculating line, and suction line from the deaerating feed tank must all be open. The discharge valve of the pump should be closed. The shaft packing gland sealing and water connections, if fitted, are open. After the pump is started, the speed and pressure should be gradually increased to normal. Open the discharge valve of the pump and see that pressure is built up on the feed pump suction main.

Before a condensate pump is started, there must be sufficient water in the condenser hot well so that the condensate pump will not run dry. If there is no water in the condenser, about 50 to 150 gallons should be supplied from the deaerating feed tank. The pump may then be started as follows:

1. See that the vent line to the condenser shell is open.
2. Open the packing sealing water connections.
3. Open the recirculating line valve.
4. Lower the water level in the condensers to normal by allowing the surplus to discharge to the deaerating feed tank. Make sure that there is sufficient recirculation to prevent the pump from running dry.

## Care and Maintenance of Pumps

The general maintenance factors discussed in this section apply to all centrifugal pumps.

Carbon Packing Installations. The first rule for carbon packing installations is to follow the manufacturer's instructions. These instructions are the result of numerous tests and vast experience, and are far superior to any hints

that may be offered by sympathetic fellow "carbon sufferers." When carbon packing is defective, it should be removed or spotted in—or, if necessary, replaced.

In the first place, carbon packings are designed to have shaft clearances, and under no circumstances should the clearances be reduced below the dimensions given by the manufacturer. In actual practice, carbon packings have been found to operate perfectly with a running clearance 50 percent greater than the original. The coefficient of expansion of carbon is only 25 percent that of steel. Therefore, it is necessary to make proper allowance for shaft expansion so that, during operation, the carbon packings will not touch the shaft.

Care of Lubrication Systems. Lack of proper lubrication is the primary cause of all pump failures. Before a pump is started, all grease cups and bearing housings should be checked to see that they are filled with lubricant and that no water, or foreign matter, is present. See that the water flingers between the pump shaft stuffing box gland and the bearing housing effectively prevent water from the pump glands from following along the shaft and entering the bearing housing. Occasionally you will find that sleeves fitted on pump shafts do not fit the shaft tightly and water can leak under the shaft sleeves. If such leakage exists, care should be taken to prevent water from entering the bearing housing.

When starting a pump, check the oil pressure and the oil flow to and from all bearings, including the thrust bearings, being sure that the attached lubricating oil pump has primed itself. See that the cooling water is flowing through the oil cooler—or cooling coils in the oil reservoir—and that all air is vented from the water side of the oil cooler. It may be necessary to free the lubricating oil system of air in order to maintain a steady oil pressure. To do this, open the air cocks on the high points of the lubricating system; but the cocks must be closed again as soon as oil appears. Check the oil reservoir to see that it is free of water. Check the bear-

ing housing to see that no water from the pump or turbine glands is entering the lubricating system.

Oil in the lubricating system should be renewed if it is found to contain foreign matter or other impurities.

Care of Couplings and Shaft Alignment. It should be borne in mind that a flexible coupling connecting the driving unit to a centrifugal pump is intended to take care of slight, but not serious, misalignment. If misalignment is excessive, however, the coupling parts are subjected to severe punishment, necessitating frequent renewal of pins, bushings, and bearings.

A high-grade oil having the viscosity characteristic indicated by Navy symbol 5190 should be used as the coupling lubricant. The coupling should be completely filled with oil before the unit is started for the first time, and fresh oil should be added at regular intervals to ensure an ample supply at all times. The oil hole plugs should always be replaced and securely tightened after oil has been added. At least twice a year, the coupling should be opened, cleaned, and refilled with fresh oil.

Shaft alignment should be checked frequently. If the shafts are out of line, realignment of the unit should be undertaken. Otherwise, shaft breakages may occur, and bearings, pump casing wearing rings, and throat bushings will have to be renewed. Whenever practicable, the alignment should be checked with all piping in place, and all tanks and piping filled; allowance should be made for change in position of parts from the cold-check condition to the hot-operating condition. Because of high steam, exhaust, and water temperatures aboard Navy ships, allowance for change in alignment resulting from variations in temperature is assuming an ever-increasing importance. The necessity for allowing for expansion of parts cannot be overstressed.

Inspection of Bearings. Thrust bearings should be examined quarterly and the position of the rotors checked. When the rotor position is checked, due allowance should be

made for expansion of the shaft from cold condition to hot running condition.

Most vertical condensate and circulating pumps of recent design, and many main circulating pumps, are fitted with an internal water-lubricated bearing inside the pump casing. With this type of bearing, there must be an adequate supply of clean water for lubricating and cooling the bearing.

The condition of all types of internal water-lubricated bearings should be checked regularly, to guard against excessive wear, which would result in misalignment and possible shaft breakages.

INSPECTION AND RENEWAL OF WEARING RINGS. The clearance between the impeller and the casing wearing rings should be maintained as shown on the manufacturer's plans. Where drop in pressure across the wearing rings does not exceed 150 psi (as on circulating, flushing, condensate and other low-pressure pumps) the loss in capacity, resulting from wear, is not as great as with high-pressure pumps (such as boiler feed pumps). The same amount of wear in a small pump will cause a much larger percentage of reduction in capacity than in a large pump. When the capacity of the pump is reduced by 5 to 10 percent, the wearing rings should be renewed. A periodic examination should be made on all pumps to check the clearances and condition of wear of all parts. The engineer officer should decide whether the amount of wear on the clearance rings warrants renewal. It is considered that wearing rings will not require renewal unless the wear amounts to at least 0.015 inch.

### Dynamic Balancing of Rotating Parts

All pump and driving unit rotating parts are balanced dynamically for all speeds from 0 to 125 percent of rated speed. The parts are usually balanced on balancing machines, generally available only at naval shipyards. However, a PORTABLE balancing outfit (Davey vibrometer) is available on tenders for use of individual ships.

The pump and turbine rotors may be balanced in place with a portable unit. Whenever possible, the balancing machine or the portable balancing outfit should be used in preference to any other method of balancing.

In all cases the elements of each pump rotor are balanced individually in order to keep all parts interchangeable. Under no circumstances should balance be corrected on a completely assembled unit. If a rotor becomes unbalanced, it will be absolutely necessary to dismantle the rotor completely to determine and correct the individual part which is out of balance.

## Major Troubles and Repairs

A list of the principal troubles that may occur with main condensate, main booster, and other centrifugal pumps, together with their causes, is given below. In the majority of cases the trouble is external to the pump, and these causes should be carefully investigated before undertaking repairs:

1. FAILURE TO DELIVER WATER:
    a. Pump not primed
    b. Insufficient speed
    c. Impeller plugged
    d. Wrong direction of rotation (this may occur after motor overhaul)
2. SHORT IN CAPACITY:
    a. Air leaks in suction of stuffing boxes
    b. Insufficient speed
    c. Insufficient suction head for hot water
    d. Suction strainers fouled
    e. Impeller partially clogged
    f. Mechanical defects; wearing rings worn; impellers damaged; and casing packing defective
3. PRESSURE LOW:
    a. Insufficient speed
    b. Air leaks
    c. Incorrect discharge valves open in manifold (this may allow the pump to discharge into an

open line, causing the pump to operate at other than the design point)

d. Mechanical defects, same as 2, f, above

4. PUMP LOSES WATER AFTER STARTING:

a. Leaky suction line

b. Water seal plugged

c. Suction lift too high (often caused by fouling of the strainer after the pump is started)

d. Air or gases in water

5. PUMP OVERLOADS DRIVER:

a. Speed too high

b. Liquid of different specific gravity and viscosity than normal

c. Rubbing caused by foreign matter in the pump, and between the case rings and the impeller

d. Mechanical defects: rotating element binds; shaft bent; and worn bearings

6. PUMP VIBRATES:

a. Misalignment

b. Poor foundation

c. Impeller partially clogged, causing unbalance

d. Mechanical defects, same as 5, d, above

If the pump fails to build up pressure when the discharge valve is opened and the pump speed increased, take the following steps:

1. Secure the pump.
2. See that the pump is primed and that all air is expelled through the air cocks on the pump casing.
3. See that all valves on the pump suction line are open.
4. Start the pump again. If the discharge pressure is not normal when the pump is up to its proper speed, the suction line may be clogged, the diffusion vanes clogged, or an impeller broken. It is also possible that air is being drawn into the suction line or into the casing. If any of these conditions prevail, stop the pump and notify the engineer officer.

The parts most frequently requiring repair or replacement are:

1. Case rings and impeller rings. Since the purpose of these rings is to keep the internal bypassing of the liquid to a minimum, the clearance should be checked periodically and whenever the pump casing is opened up.

2. Shaft sleeves. There is a common tendency of operating personnel to take up too hard on the packing in an attempt to stop stuffing box leakage. This causes scoring of the shaft sleeves. Whenever the pump is opened, the sleeves should be examined and if not badly scored, they should be smoothed up; if they are badly scored, they should be replaced.

3. Bearings. Worn sleeve bearings cause the rotor to drop; this, in turn, results in wearing of the case and impeller rings.

Occasionally trouble is experienced from the impeller coming loose on the shafts because of a key corroding. Monel metal keys do not corrode and have given good results.

When a pump is being repaired, worn parts should be removed and replaced. When a pump has been repaired, it should be operated and checked for satisfactory operation.

### Inspection of New Condensate and Booster Pumps

It is noted by BuShips that damage to subject pumps has been experienced, in varying degrees, on new construction during shipboard tests and dock trials.

Each pump is thoroughly tested and adjusted during the performance acceptance tests at the manufacturer's plant. If the pumps are properly installed, no operational difficulties should be expected. When installing the pump units on their foundations, care should be taken to ensure against misalignment. After the pump is bolted down, the alignment of the pump with its driving unit should be corrected prior to the operation of the unit. All piping leading to and from the pump should be well supported without regard to the flange bolting at the pump, and should line up naturally. If the flanges do not exactly match, the piping should be corrected so that the faces are square and the bolt holes are in line. Care in the fitting and supporting of piping pre-

cludes a possible distortion of the pump unit due to initial piping stresses.

If pumps are designed to handle hot water and are tested with cold water, or if they are designed to handle cold water under vacuum and are tested with handling water under atmospheric pressure, they will have high excess capacity. For this reason the pump should be tested with the suction valve wide open and the discharge valve open about ½ turn. After the pumps have reached full speed, the discharge valves should be adjusted to circulate a reasonable volume of water without imposing an abnormal load on the units. These pumps, if handling hot water, can be operated against shut-off pressure for a reasonable length of time, without encountering trouble resulting from vaporization or excessive overheating. Booster pumps handling cold water can be operated at comparatively low capacity, or against shut-off pressure, much longer than hot-water pumps.

## MAIN FEED PUMPS

Before starting a main feed pump for the first time, carefully read the instructions for the pump and the turbine. See that all slushing compound and dirt which may have accumulated during storage is removed. Then proceed as follows:

1. Check the oil reservoir for cleanliness.
2. Fill the oil reservoir with lubricating oil (Navy Symbol 2190T) to operating level.
3. Fill the bearings with the same lubricating oil by removing the filling plugs on the bearing cap. Make certain that the filling plugs are tightened after bearings have been filled.
4. Fill the coupling with lubricating oil (Navy Symbol 3080), NEVER LIGHTER THAN SAE 40.
5. Check the alignment between the pump and the turbine rotor.
6. Turn the unit at least one complete revolution by means of a strap wrench, and make certain that the unit rotates freely.

7. See that the stuffing boxes are packed with plastic packing, specification 33–P–25 Symbol 1433–type B, furnished by the contractor.

8. Fill the pump with liquid by opening the suction valve. Allow air to escape through the vent valves, located at the top of the upper half pump casing. Close the vent valve after all the air has been eliminated.

9. Open the recirculating line.

10. Start the turbine (check starting instructions in the manufacturer's instruction book). When the unit is up to speed, open the discharge valve slowly. The pump is now ready for operation.

### Putting the Feed Pump on the Line

If the feed system is of the closed type and a main feed pump is to be operated, see that the proper feed booster pump has previously been started and is maintaining a pressure of approximately 50 psi on the feed pump suction main.

Water from the main feed booster pump enters the first-stage suction casing under pressure and is discharged through the first-stage impeller into a built-in connection which leads to the suction of the second-stage impeller. Passing through the second-stage impeller, water is discharged under high pressure, approximately 750 psi, into the main feed line. There are two sets of wearing rings in each stage, since the impellers are double entry. The designed clearance of these rings is approximately 0.008 inch. Since these rings have the same clearance as those in the condensate and feed booster pumps, and the speed of rotation of the main feed pump is five times as great, the possibility of seizure of the rings is also much greater. The main feed pump is subject to the same casualties as the main condensate and the main feed booster pump—even more subject to these casualties, because of its high speed of rotation.

Water entering the suction of the first stage from the booster discharge line has its pressure reduced while passing through the entrance ports, and since this water is under a temperature of about 240° F, this reduction in pressure

might easily be the cause of the water flashing into steam. If this occurs, the first-stage impeller will become vaporbound and prevent the flow of water to the pump from removing the generated heat. If the main feed pump becomes vaporbound, it will require only about 15 seconds for the pump to overheat and seize, due to the high speed of rotation. The pressure leading to the pump suction from the main feed booster should be maintained at as high a value as practicable. Under no circumstances should a main feed pump ever be turned over unless there is a minimum pressure of 40 psi to the suction of the pump. The normal discharge pressure of the pump is approximately 50 psi. Vapor entering the pump from any source is carried away through a vent provided for that purpose. This vent is necessary in the first stage only, since the pressure in the second stage will prevent the accumulation of any vapor. When the main feed pump is started, the first-stage vent must always be open to carry away any accumulation of air or vapor trapped in the pump casing.

## Operating Checks and Precautions

When the main feed pump is operating, check the oil supply to the bearings. The pressure gages at the bearings should read approximately 5 to 8 psi. The maximum temperature at the oil return lines should not exceed 160° F.

Adjust the stuffing boxes, making certain that a small amount of water is constantly leaking out of the boxes. This water provides lubrication to the packing and tends to keep the stuffing boxes cool. Be sure that the gland is at all times parallel to the face of the stuffing boxes and is not cocked at an angle. If stuffing boxes leak too much and it becomes necessary to take up on the packing, tighten the gland bolts (one at a time) for not more than ½ turn.

When the pump is running, do not change from hot water to cold water or vice versa, unless an extreme emergency arises. Make periodic observations as to the vibrations of the rotating element. If vibration becomes excessive, stop

the pump and investigate. Vibration may be due to clogging of one or more impellers or volute passages by foreign materials, to misalignment with the driving unit, or to increased bearing clearances.

Precautions should be taken to see that the pumps are not operated if any of the following conditions exist:

Capacity is too low.

Pressure is too low.

No water gets to the pump.

Speed is too low.

Suction pressure is low.

Foreign material has accumulated in the casing or in the impeller passages.

### Casualties to Main Feed Pumps

Reports of casualties to main feed pumps indicate the need for reemphasis of the following operating and maintenance instructions:

1. Inspect the lube oil sumps for the presence of water, prior to each starting of the pump.
2. Check the position of the rotor prior to each starting and at least once each watch thereafter.
3. Shift the pumps daily when underway.
4. Where water leakage through the main feed pump shaft is excessive, ensure that the babbitt packing, threaded on the ends of the shaft protecting sleeves, is tight, prior to taking up on the shaft packings. Excessive tightening of the shaft packing results in scoring of the shaft protecting sleeves without appreciably reducing the amount of leakage.

### Stopping and Securing the Pump

To stop and secure, proceed as follows:

1. Close the pump discharge valve.
2. Close the throttle valve.
3. Close the exhaust valve.
4. Close the vent valves.
5. Close the recirculating and the gland leak-off line valves.

6. Close the valves to the gland water seals.

7. Close the pump suction valve.

8. Open the turbine drains.

9. Close all delivery and return oil valves if the pump is lubricated by a detached pump.

10. Close the steam and the exhaust root valves.

11. Close the steam drain after the turbine is completely drained.

### Dismantling of Pump

In order to dismantle a main feed pump properly, proceed as follows:

1. Drain water from the casing.
2. Remove the bearing caps, the bearing bushings, and the thrust shoes. (Remove the parts in the sequence recommended in the manufacturer's instruction book.)
3. Disconnect the couplings, remove the bolts, and break the coupling joint.
4. Remove the gland and the packing.
5. Remove the nuts of the pump casing around the parting flange, at the top and bottom of the flange.
6. Pull out the parting flange dowels.
7. Break the parting flange joints by tightening the jack screws.
8. Attach the lifting gear to the upper half casing, in eyebolts provided for this purpose.
9. Lift the upper half casing straight up until it has cleared all the rotor parts.
10. Remove the rotor from the casing. Attach cables around the shaft at both ends between the bearing flingers and the shaft sleeve nuts and lift the rotor vertically until it is clear of the casing.

### Dismantling of Pump Rotor

In order to have access to all the rotor parts, place the rotor on a work bench or on two wooden horses.

Starting first at the outboard end, and then at the inboard end, remove the rotor parts, in the sequence recommended in accordance with the manufacturer's instructions.

For removing impellers from the shaft, warm the impeller evenly all around, keeping the shaft as cool as possible.

### Assembling the Pump Rotor and Pump

In assembling the pump rotor, clean all parts thoroughly and make certain that the parts (especially the faces of the impeller hubs and sleeves) are free of burrs. Mount the parts on the shaft, in accordance with the manufacturer's instructions.

In assembling the pump, clean the casing connections thoroughly and check the parting flange gasket. Make certain that the gasket is in perfect condition, especially around the casing parts holding the diaphragms and casing rings. If the gasket is cut or torn, replace it with a new one.

### Installation of New Parting Flange Gasket

Clean the parting flange and make certain that all old gaskets are removed. Shellac a sheet of new gasket material to the lower parting flange, put both halves of the casing together, and allow the shellac to dry. Remove the upper half casing and cut the gasket accurately around the hydraulic passages and especially around the casing parts.

### Installing the Rotor in the Casing

Attach the lifting gear cables on both ends of the rotor between the flingers and the shaft sleeve nuts.

Lower the rotor into the casing. See that all the stationary rotor parts (diaphragms, casing rings, and stuffing box bushings) can easily enter their respective positions in the casing. If force must be applied in order to position the casing parts, remove the rotor once more and check both the casing and the rotor parts for dirt and burrs.

Close the casing by lowering the upper half casing over the rotor. See that the casing aligns properly with the rotor parts. If it does not, remove the upper half casing again and examine it for dirt and burrs.

After both casings contact each other at the parting flange, insert the casing dowels and tighten the parting flange nuts. Tighten the nuts evenly by going over them several times, preferably with a box socket wrench.

### Alignment and Assembly

When you are assembling the turbine with the pump, make certain that the turbine and pump are in correct alignment.

Check the alignment with the halves of the coupling housing, slid back sufficiently to be able to check on coupling hubs. The necessary tools are a straightedge and a set of feelers, or thickness gage. If preferred, a finished steel wedge of fine taper, instead of feelers, may be used for comparing distances between coupling faces at several points (at least 90° apart) around the coupling.

If both coupling hubs are the same size, and true with the shaft, the unit will be in line (1) when the feelers show the coupling faces to be parallel, and (2) when a straightedge, laid across the rims of the coupling hubs at several points, shows contact the full width of both rims.

If careful examination shows that the coupling halves do not run exactly true, one of the two units will have to be moved up or down, or shimmed, to bring it into line with the other. To check the faces of a coupling, measure the distance between the faces at the top of the coupling hubs. Rotate both coupling hubs 180° and check the distance between the faces at the bottom of the coupling hubs. If the two clearances are the same, the unit is in line.

## REPLACING A ROTOR IN A CENTRIFUGAL PUMP

In replacing a centrifugal pump rotor, the MM1 or C in charge should plan the job so that the work will progress smoothly and without any mistakes or accidents. The repair job should be performed in accordance with best workmanship standards. The following procedures should be taken:

1. Obtain the manufacturer's instruction book and blueprints for the pump to be repaired. Review or study the

construction details and the procedures for disassembly and assembly. Note the manufacturer's data on clearances and tolerances on bearing, shafts, and similar dimensions. Review the Machinery History Card on the pump to be repaired (in certain cases alterations may have been made).

2. Remove the spare pump rotor from its stowage place on board ship. The pump rotor should be in good condition and balanced. Clean and inspect the spare rotor. Take the necessary measurements.

3. Assemble all the necessary tools and equipment (including special tools).

4. Remove steam and other piping, as required.

5. Lift the rotor casing.

6. Inspect the rotor.

7. Lift out the old pump rotor.

8. Make a thorough inspection of the interior of the pump upper and lower casing, journal bearings, thrust bearing, and other parts, including assemblies, of the pump.

9. Replace, with repair parts carried on board, any defective bearings or other malfunctioning parts.

10. Clean and oil all parts as necessary.

11. After the cleaning and inspection are completed, lower the rotor into place, in the lower casing (Horizontal Pump).

12. With the rotor in place, check all measurements and clearances. These readings should compare with the specified data on measurements given on blueprints or in the manufacturer's instruction book.

13. Give particular attention to journal and thrust bearings. The pump rotor should be set in its design position.

14. See that flanges, etc., are clean and in satisfactory condition.

15. When the inspection and any adjustments have been completed, lower the upper casing into place. The pump flange gasket should be of proper material and thickness.

16. With the upper casing in place, check for freedom of movement by manually turning the rotor.

17. Bolt the upper casing down and check the movement of the rotor.

18. When the job has been completed, slowly turn the pump over by steam.

19. If all conditions are satisfactory, the turbine and pumps should be brought up to operating pressure and given such tests as may be practicable.

20. The pump should not be considered ready for unlimited operations until it has carried the required load, with the ship under way. When the pump is put on the line for the first time, it should be kept under close observation for a number of hours.

21. Prepare a request for repair parts to replace those that have been expended. As practicable, a full allowance of repair parts must, at all times, be maintained on board.

22. Prepare a request, or rough work request form, for the required repairs to the defective pump rotor. All pertinent details, including balancing, should be written up before the old pump rotor is stowed away.

23. See that the Repair Request Card is properly filled out and placed in the CSMP. This ensures that the repair item will not be overlooked, and that the necessary work will be accomplished at the first available repair period.

24. The pertinent details and information on the pump overhauled should be entered in the rough work book so that the proper entry can be made on the Machinery History Card for the pump.

25. The paper work should be completed as soon as practicable, while the machinery is available for detailed inspection, and before any important work details have been forgotten.

## MAIN CIRCULATING PUMPS

The capacity required by the circulating pump is governed by 3 factors: (1) the amount of steam to be condensed, which varies with the load; (2) the temperature of the circulating water; (3) the vacuum that is being maintained on the condenser.

The total head against which the main circulating pump operates is made up of two principal factors: (1) static head, which depends on the location of the condenser and draft of the ship; (2) friction loss through condenser tubes, heads, piping and fittings. The latter constitutes the greater portion of the head, and in many cases the head is all friction loss. The friction loss varies approximately as the square of the rate of flow, which means that there will be considerable variation in the operating head. Due to the fact that both head and capacity may vary considerably, it is necessary to use variable speed drive, either motor or turbine.

### Starting Precautions

Never operate the circulating pump unless the casing is filled with water. The internal pump bearing requires water for lubrication. The packing should be set up lightly and slight leakage should occur from the stuffing box to prevent unnecessary wear and consumption.

### Dismantling and Reassembling

The pump casing is split on the horizontal centerline and the pump rotor can be inspected by removing the case cover. After the coupling is disconnected, the rotor can be lifted out. The bearing sleeve is split and can be removed or replaced without removing the rotor.

Before reassembling, clean all parts, scrape the flange faces clean, and install new gaskets where required.

### Alignment of Pump

The pump must be lined up properly with its turbine, as the unit is fitted with a rigid flanged coupling which cannot compensate for any misalignment. The rotating element should turn freely after the unit is in position and all the piping connected. The piping should line up naturally with the pump flanges and should be supported independently of the pump. Forcing the pipe into line with the pump tends to throw the pump out of alignment.

## MAIN LUBE OIL PUMPS

On surface vessels, particularly those of recent construction, main lubricating oil pumps are subjected to severe operating conditions if air has entered the lubricating oil. The pump should be vented until all air is eliminated from the casing.

### Disassembling the Pump Rotors

Neither the main lube oil pump nor the drive can be dismantled in place, therefore the removal of the drive is a necessary preliminary step to any disassembling operations.

With the drive unit removed, the pump rotor and rotor housings can be completely dismantled without disturbing the mounting or the main oil connections. (See fig. 6–4.) Removing the drive unit is simply a matter of breaking the steam, water, drain, and oil seal connections, disconnecting the coupling, taking out the bolts which secure the spacing frame to the pump casing, and lifting the unit off intact.

For detailed step-by-step instructions, refer to the manufacturers' operation and maintenance instruction pamphlets. For some steps, the special tools furnished for the pump, or other suitable pulling tools, must be used.

In the pump dismantling process, first remove the half coupling, the packing gland, and the upper casing head. The next step is to withdraw the rotors. Keep in mind that the idlers must be supported as the rotors are withdrawn from the housings, since the pump construction is such that the housings alone hold the rotors in mesh.

With the rotors out, the rotor housings are accessible. These parts fit snugly in the bore of the casing, where they are separated by a spacing ring. They are positioned axially by jam screws, which bear on the casing heads, and circumferentially by guide pins which are fitted individually to ensure alignment of the housing bores. The guide pins are secured by pipe plugs. Before the rotor housings can be removed, it is necessary to take out the housing guide pins, the outer ends of which are drilled and tapped for the application of a pulling tool. The guide pins are fitted parts,

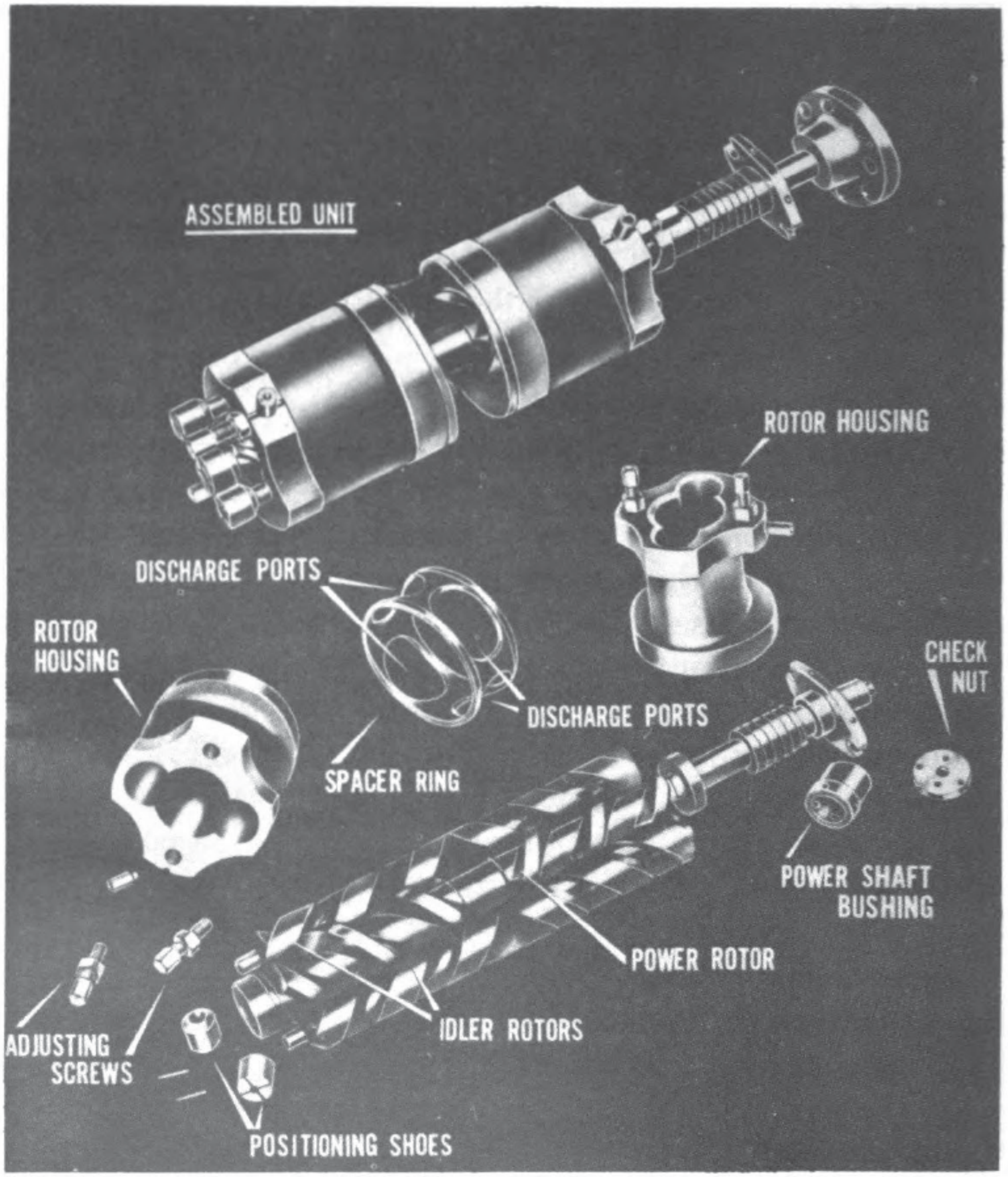


**Figure 6-4.—Pump rotors and rotor housings.**

therefore each pin should be marked as it is withdrawn, so that it can be replaced properly.

## Assembling Operations

Before the assembling operations are started, all parts of the pump should be carefully inspected and cleaned. Also, it should be definitely ascertained that the settings of the lower housing jam screws are correct. (Check the manufacturer's pamphlet or blueprint.)

Lower the bottom housing, the spacer, and the upper housing into place separately, seating each part firmly and making sure that the guide pin slot in each housing registers with the pin hole in the casing. (The special tool used for withdrawing the housings can also be used to advantage in assembling operations.) Install the housing guide pins and their securing plugs. If new housings are installed, the bores must be carefully aligned and new guide pins fitted to maintain the alignment. Set up the jam screws in the upper housing.

Insert the rotors and see that they turn freely in place. Binding of the rotors is an almost certain indication that the housing bores are not in line or, in other words, that either the guide pins or the housings themselves, or both, have not been properly installed. Install the casing head, and see that the thrust plate and the seal bushing are in place and that the latter is secured by the stop pin provided for that purpose. Manila paper gaskets 0.010 inch thick should be used for the joints between the casing heads and the casing proper. Install the packing and the half coupling.

### Rotor Settings

When a pump is assembled at the factory, the nitrided steel locating caps on the idlers are set up to establish the proper running position of the idlers with reference to the power rotor, and are then secured by riveting. So long as a set of rotors remains intact, readjustment of the locating cap settings rarely will be found necessary because even over long periods of service, wear of the hardened contact surfaces is negligible.

However, whenever new rotors are installed the proper locating cap settings must be established. The proper cap settings are such that the lower end surfaces of all these rotors lie in a common plane when the rotors are properly meshed and the idlers are located CENTRALLY with respect to end play in the power rotor. The cap settings must be established before the rotors are installed. In order to ensure proper meshing, the rotors should be inserted in one of the

housings for the adjustments. A tapped hole is provided in the base of each cap, so that the pulling tool, or some other suitably threaded implement, can be used to jack the cap into position. After the settings have been established, the caps should be riveted in place. This entails drilling of the shaft ends for the rivets. Rivet holes are provided in the caps of all idlers supplied separately by the factory, and a rivet is furnished with each idler.

## SHAFT-DRIVEN LUBE OIL SERVICE PUMPS

These pumps are hooked up to the propeller shafts through sprocket and chain transmissions so that they are operated continuously while the main shaft is turning over. These pumps are designed with vertical shaft or horizontal shaft units.

### General Design and Operating Characteristics

The units are of the same size and basic design as the steam-driven pumps, but differ in the mountings and the drive details affected by the mountings.

The driven sprocket of the transmission for the vertical pump is mounted on a jack shaft which is geared to the power rotor, whereas the corresponding drive member for the horizontal unit is mounted directly on the power rotor shaft. The casings and all corresponding internal parts are interchangeable.

Each shaft-driven lubricating oil service pump has three double-acting hydraulically balanced rotors which work together in two close-fitting housings, secured in the casing. The power rotors are mounted in ball bearings and there are no stuffing boxes, but otherwise the construction is the same as in steam pumps.

The chain drives are enclosed by welded steel casings which are mounted on supporting frames bolted to the pump flanges. Each casing is made in sections, so that the drive can be dismantled readily, and openings with hinged cover plates are provided in the top and sides of one of the cover sections so that the mechanism can be inspected without the necessity for

opening the casing. A lucite window in the top permits observation of the drive in operation.

Oil is supplied by the pump itself, through a ½ inch connection, for the lubrication of the driving mechanism, the pump bearings, and the sealing of the pump casing against the intake of air where the driving end of the power rotor emerges. The ½ inch connection runs from a filter, connected to the discharge compartment of the casing, to the various points where direct oil flow is required. A sight feed valve is provided in the oil feed line for the chain drive so that the flow of oil to the drive can be regulated according to the requirements for keeping the drive casing properly drained. The oil system functions automatically, and apart from adjustments of the sight feed valve and the regular cleaning of the filter, it requires no attention when the pump is in service.

### Disassembling the Pump Rotors

Before a pump is disassembled, the DRIVE must be completely dismantled as follows:

1. Disconnect the oil lines running to and from the chain casing.
2. Remove the cover sections of the chain casing.
3. Break and remove the chain. A special drift for use in this connection is attached to one of the cover sections of the casing, together with a plate on which are inscribed detailed instructions for the application of the tool.
4. Detach the lower section of the chain casing from its supporting frame.
5. In the case of the vertical unit, remove the frame which supports the chain casing and houses the drive gears. The drive shaft mounting need not be disturbed for this operation.

With the driving mechanism out of the way, the horizontal pump can be dismantled in place, provided there is a clearance of not less than 44 inches between either end of the casing and the nearest object, for the withdrawal of the rotors. The vertical unit, however, must be detached from

its base and transferred to a support where both ends of the casing are accessible and the rotors can be withdrawn.

Space permitting, the rotors can be withdrawn from either end of the casing but it will be found that withdrawal from the outer end (the end away from the drive) is the simpler process, because it does not necessitate the removal of the inner casing head. Removal of the outer casing head, however, is a necessary preliminary step of the disassembling operations.

Removal of the rotors from the outer end of the casing is simply a matter of taking off the sprocket, or drive gear, as the case may be, with its key; locating the liner; tapping the inner end of the power rotor (if necessary) to free the rotor; and withdrawing the rotor assembly.

With both casing heads off, the rotor housing can also be withdrawn from either end of the casing. The housings should be removed by using the pulling tools which are generally furnished with the steam pumps. The housings and guide pins, like the corresponding parts of the steam pumps, are fitted individually and should be marked as they are withdrawn, so that they can be replaced properly.

The procedure to be followed in the disassembling of the inner casing head unit and the removal and stripping of the jack shaft in the gear box of the vertical unit will be apparent from a study of the assembly cuts and the parts themselves.

## Assembly Operations

As far as the shaft-driven pump is concerned, the assembling operations are essentially the same as those described in this chapter, in the section "Main Lube Oil Pumps." The jam screws in the rotor housing at the end of the casing which is to be closed first should be adjusted to extend 3½ inches from the face of the housing. It is not advisable to install the inner casing head until the rotors are in place.

To assemble the driving mechanism, the dismantling operations are reversed. Before the chain casing is closed, it should be ascertained that the location of the driven sprocket

with reference to the main drive is in accordance with the blueprints or manufacturer's plans, and that the two sprockets are in line. The position of the driven sprocket is determined by the thickness of the adjacent locating liner. An error in the sprocket setting indicates that the liner must be refitted or replaced with a liner of the required thickness. If the driving and driven sprockets are not in line, the error should be rectified by shifting, as required, the driving sprocket on the propeller shaft.

The bevel gears in the vertical pump drive should be meshed according to the marks on the teeth and checked for tooth contact after they are assembled. Satisfactory performance requires full tooth contact on the driving side of the teeth. The degree of contact can be determined by coating the pinion with prussian blue, jacking the rotors in the normal direction of rotation, and then examining the tooth surfaces. Insufficient tooth contact indicates the need for adjusting the positions of the gears on their respective shafts. This entails the refitting or replacement of the adjacent locating liners.

### Setting Up New Rotors

When new rotors are installed, the idler locating caps should be set up so that their outer end surfaces lie in a common plane separated from the plane of the casing joint surface by 0.482 to 0.485 inch. These adjustments must be made with all parts of the pump in place, except the outer casing head unit and the outer ball bearing.

## PUMP REGULATING DEVICES

Turbine-driven centrifugal pumps are fitted with speed-limiting governors, set to give a rated speed, at rated load conditions. The governor is set to limit the speed to a maximum value. With the governor set in this manner, the turbine speed should not exceed the rated speed by more than 5 percent for any condition of load, including shut-off of the pump. If the governor will not function within the pre-

scribed limit, it should be overhauled and the cause of faulty operation located and remedied. Speed-limiting governors should be tested at least once every three months and after each overhaul.

In addition, most main feed pumps are fitted with constant-pressure governors as well as with speed-limiting governors. A constant-pressure governor is illustrated in figure 6–5.

### Leslie Constant-Pressure Pump Governor

The function of this governor, shown in figure 6–5, is to control steam pressure admitted to the pump propulsion unit, so that the fluid discharge is maintained at a constant preset level. This governor is used on main feed, lube oil service, or fuel oil service pumps. The principles of operation are the same for all three; the primary difference is in the size of the upper diaphragm, which decreases as discharge pressure increases.

The adjusting spring pressure of the valve is exerted on the upper diaphragm through a crosshead and mushroom. With no pump discharge pressure, the spring forces the upper diaphragm down, and the upper crosshead also moves down. A pair of connecting rods connect the upper crosshead with a lower crosshead, therefore the lower crosshead will be moved down with the upper one. When this action occurs, the lower diaphragm will be displaced downward by the lower mushroom, and when it comes in contact with the auxiliary valve stem, it forces the disk open, admitting steam to the operating cylinder. This forces the piston down, opening the main valve and admitting steam to the pump propulsion mechanism.

As the pump discharge pressure builds up, pressure is exerted against the upper diaphragm through the control connection. When the force below the diaphragm is greater than the spring force, the diaphragm is deflected upward, forcing the upper and lower crossheads up and allowing the auxiliary valve to close. A small port in the operating piston

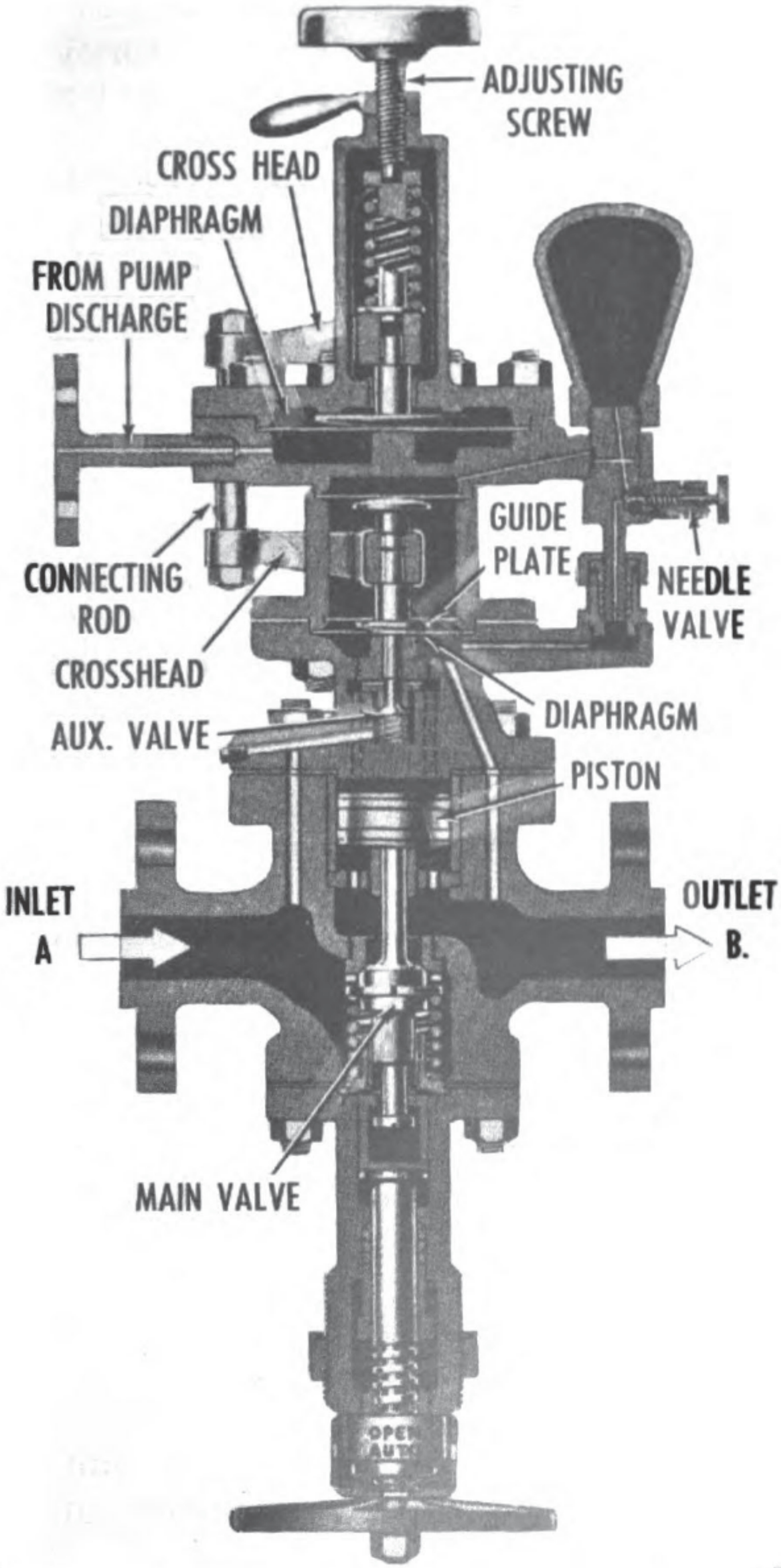


**Figure 6–5.—Constant-pressure governor.**

allows the steam to bleed off, thereby reducing the pressure on the piston and enabling the main valve spring to close the valve. The decreased steam pressure slows the pump and decreases the discharge pressure.

Rapid repetition of the above actions would result in a constant average discharge pressure from the pump, but the pump would hunt and the pressure oscillate. The inertia of the moving parts slightly reduces the hunting effect. The intermediate diaphragm offers resistance to the upward movement of the crossheads, slowing down the reaction of the valve and resulting in reduction in discharge pressure. Steam admitted to the chambers above the intermediate diaphragm, and below the lower diaphragm, provides a further retarding action to reduce the amplitude of the crosshead movements.

With the unit under constant load conditions, the operating piston will take up a position which will hold the main valve open by the amount required. With a change in load conditions, there will be momentary hunting, until the governor finds the new position required to maintain the pressure at the new load.

Aside from the discharge pressure adjustment made with the adjusting screw, there is only one other adjustment made on this governor. The needle valve, which controls the steam pressure admitted above the intermediate diaphragm, should be adjusted to minimize hunting. This adjustment should be made with the pump operating under light load at normal discharge pressure. The needle valve is normally adjusted by turning it approximately 1/4 of a turn open. IT MUST NEVER BE SHUT TIGHT.

The lower stem of the main valve carries a yoke which surrounds a flange extending from the bottom of the valve disk. With the stem screwed in, the disk is free to operate under control of the operating piston and the unit is, therefore, on AUTOMATIC. When the stem is screwed out, the yoke catches the flange and pulls the disk open, allowing a full flow of steam to pass to the pump driving unit. In this position, the pump must be controlled by hand, with the

throttle valve. The unit should be left in the AUTOMATIC position, except during emergencies when it is necessary to use the hand throttle.

### Atlas Constant-Pressure Pump Governor

This type of governor has recently passed type approval tests and will be installed on naval ships in the near future. The Atlas governor operates on the same principles as the Leslie governor. The major difference between the two types is in the needle valve arrangement.

### Foster Constant-Pressure Pump Governor

The function of this valve is to automatically control the amount of steam admitted to the driving end of a steam-driven pump, in order to maintain the fluid discharge pressure at a predetermined constant level. This type of governor will be found on some ships, although general specifications for machinery now prohibit the use of a bellows, which has proved troublesome.

### Maintenance and Repair of Governors

The instructions for operation, care, and repair of pressure governors contained in this chapter are general for all makes and types of governors. For specific instructions, manufacturers' pamphlets for the various types of governors may be consulted.

CLEANING AND REPAIRING. Sluggishness is caused by dirt or foreign matter, carried with the steam into the governor, and interfering with the free movement of the working parts. To correct sluggishness, particularly with the Leslie governor, the governor must be taken apart and cleaned as follows:

Unscrew the connector union, remove the bottom nuts from the stud bolts holding the superstructure to the top cap, and lift off the superstructure above the lower diaphragm, without further disassembling. The superstruc-

ture does not contain any moving parts except the diaphragms and normally does not need to be taken apart except when a replacement is made. When it is necessary to disassemble the superstructure, care must be taken that the diaphragm stem, diaphragm stem cap, and diaphragm disk are put back in proper position. Make sure that the connecting rods are free in their guides and do not bind because of paint or carbonized oil.

Unscrew the controlling valve seat, with the special wrench provided for this purpose; remove the controlling valve and the controlling valve spring.

Remove the top cap and lift out the piston and the cylinder.

Remove the bottom cap and take out the main valve and the main valve spring.

Clean the parts. See that the main valve and the controlling valve seat properly and that the piston rings are perfectly free in the piston grooves. Clean the seat for the cylinder liner so that the cylinder liner does not project above the face of the top flange of the main body. Clean the bore of the main valve guide. Regrind the main valve with the piston in the cylinder. The stem of the controlling valve must never project above the seat of the diaphragm. The correct clearance is 0.001 to 0.002 inch below the diaphragm seat.

When tightening up the stud bolts for the superstructure, pull down evenly without using excessive strain.

When renewing diaphragms and gaskets on Leslie governors, be sure to use standard parts made by the Leslie Company. The correct thickness of diaphragm must be maintained. Do not put gaskets under diaphragms.

Do not use substances such as graphite, lead, or cement on gaskets.

Diaphragms and Bellows. In Foster pilot-valve-operated governors, particular care should be taken to maintain the soldering of the bellows ends to the sealing rings, and the ground points of the bellows seals, in perfect condition. Any leakage at these points will cause leakage of the motivating

liquid (salt water, lubricating oil, or fuel oil) into the steam spaces of the governor, and thence into the driving unit and to the auxiliary exhaust, resulting in contamination of the feed water.

Steam Pilot Valves and Seats. In the Leslie governor, the pilot valve is continuously throttling, or wire drawing, the steam passing through it, and hence the valve and valve seat are subjected to considerable erosion. Therefore, these parts should frequently be inspected. New parts, when needed, should be of cast or forged steel, faced on the seating surface with cobalt chromium composition, or corrosion-resisting steel, grade 3H, having a minimum hardness of 300 Brinnel, not faced. Pilot valves should be of forged steel, or corrosion-resisting steel, grade 7, faced on the seating surface with cobalt chromium composition.

Piston and Cylinder Liners. On the Leslie governor, faulty governor action is frequently due to an accumulation of foreign matter in the cylinder liner causing sticking or excessive wear. The result is often a wearing of grooves in the liner, because of the movement of the piston through a short travel, as when the pump is operated at reduced capacity. When the governor attempts to open the main valve wide for full pump capacity, the travel of the valve is limited to the distance between these grooves, because the piston rings cannot get past them. Thus the governor fails to open wide.

Where replacement of parts is necessary, the liner should be made of chrome nickel semisteel, of a hardness of not less than 220 Brinell, or of corrosion-resisting steel, grade 5, hardened to 400 Brinell; the piston should be of high-test gray iron of a hardness not exceeding 180 Brinell; and the piston rings should be of the same material and hardness as the piston.

Main Valves and Seals. Governors are primarily throttling devices, and the continuous wire drawing of steam subjects the main steam valves to erosion. Where erosion is excessive, the valves and seats should be replaced with mate-

rials as prescribed in the manufacturer's instruction book, or in chapter 47 of BuShips *Manual*.

Pilot Valve Springs. Pilot valve springs should be examined occasionally to see that they are in good condition. In some of the earlier governor designs, the space around the spring was not properly drained of condensate and frequent breakage of the spring resulted.

### Safety Precautions

1. Do not tie down or otherwise render inoperative the overspeed trip, the speed-limiting device, or the speed-regulating governor.
2. See that the overspeed trips, where fitted, are set to shut off steam to the unit when the rated speed is exceeded by 10 percent.
3. See that the speed-regulating governors are set to limit the speed of the unit to rated speed, under rated conditions. In addition, see that the rated speed, for any condition of loading, is not exceeded by more than 5 percent.
4. Check, at least once each quarter, the settings of the overspeed trip and the speed-limiting device.

## SUMMARY

Since pumps are the most numerous units of auxiliary machinery aboard ship, periodic inspections and maintenance of pumps is a very important task. It will be your responsibility as an MM1 or C, to see that all pumps in the engineroom and in other assigned spaces are properly adjusted, aligned, and maintained. When repairing or examining the interior of a pump, make certain that all drawings and important dimensional data are available.

Specific instructions for each type of pump may be found in pamphlets issued by pump manufacturers. Manufacturer's instructions should be followed at all times, and particularly for carbon packing installations. Clearances between impeller and casing wearing rings should be maintained as shown on the manufacturer's plans.

Adequate clean water for lubricating and cooling should be supplied to internal water-lubricated bearings, where fitted. In addition, the condition of these bearings should be checked to guard against excessive wear which would cause misalignment and possible shaft breakages.

A centrifugal pump rotor that is unbalanced has to be completely dismantled before it is possible to locate and correct the individual part that is out of balance. When centrifugal pumps are repaired, worn parts must be carefully restored to their original sizes. After an individual pump has been repaired, it should be operated and checked to see if it works satisfactorily.

When main lube oil pumps are to be disassembled, the drive unit must first be removed. With the drive removed, the pump rotor and rotor housings can be completely dismantled without disturbing the main oil connections. Before assembling these pumps, all parts should be carefully inspected or cleaned. In addition, the settings of the lower housing jam screws must check with those in the manufacturer's pamphlet or blueprint.

The shaft-driven lube oil service pumps hooked to the propeller shaft through sprocket and chain transmissions are the same size as the steam-driven pumps. Except for the mountings and drive details affected by the mountings, they are alike in design and construction.

Every turbine-driven centrifugal pump is fitted with a speed-regulating governor. Some main feed pumps are fitted with hydraulic pressure governors, or with geared centrifugal flyball type governors. These governors are usually fitted with overspeed trips. Such trips should be set to trip out the unit when the rated speed is exceeded by 10 percent.

Main and booster feed pumps, as well as fire pumps, are often fitted with constant-pressure governors. Since most ships are equipped with Leslie governors, it is important that you understand the purpose and principles of operation of this unit.

## QUIZ

1. What will ensure even wear throughout a pump cylinder?
2. What is generally indicated by a heavy metallic knock in the steam cylinder of a pump?
3. How is the length of the stroke adjusted?
4. In general, how is the alignment of reciprocating pumps tested?
5. If a reciprocating pump is frozen, how can you determine if there is excessive friction?
6. What may cause groaning in the steam cylinder of a reciprocating pump which has been started after being idle for a long period?
7. Before fitting and installing soft packing in a pump, what step should be taken, if practicable?
8. Troubles in the steam cylinder of a pump result chiefly from what source?
9. What is the primary cause of pump failures?
10. How often should flexible couplings be opened, cleaned, and refilled with fresh oil?
11. How often should thrust bearings and the position of pump rotors be checked?
12. The wearing rings of a pump must be renewed when pump capacity has been reduced by a maximum of what percent?
13. What steps must be taken if a pump rotor is unbalanced?
14. If the suction strainers of a pump are fouled and the impeller is partially clogged, what will be the probable effect?
15. If the speed of a pump is high and the pump is binding, what is the probable trouble?
16. What pump parts require repairs or replacement most frequently?
17. If a main feed pump vibrates excessively, what should be done?
18. Precautions should be taken that main feed pumps are never operated under what 6 conditions?
19. Why is it important to review the Machinery History Card of a centrifugal pump which is to be repaired?
20. The capacity required by the circulating pump is governed by what 3 factors?
21. What is the preliminary step which must be taken before a main lube oil pump can be disassembled?
22. What must be done before the rotor housings of main lube oil pumps are removed?
23. What should be checked to determine if the settings of the lower housing jam screws of main lube oil pumps are accurate?

24. When new rotors are installed on main lube oil pumps, what settings must be established?
25. Units of shaft-driven lube oil service pumps and main lube oil pumps differ in what respect?
26. What maximum excess percentage over the rated speed is permitted for turbines of centrifugal pumps equipped with governors?
27. What is the function of the Leslie constant-pressure pump governor?
28. Hunting in the Leslie governor can be minimized by what means?
29. Why are the valve and the valve seat of a Leslie governor subject to considerable erosion?
30. How often should the settings of the overspeed trip and the speed-limiting device be checked?

# CHAPTER 7

## PROPULSION PLANT OPERATION AND SUPERVISION

The military value of a naval ship depends a great deal upon the cruising radius, which in turn depends upon the efficiency with which a given propulsion plant is operated. Economical operation involves making fuel, lubricating oil, feed water, potable water, and consumable supplies last as long as possible. A ship is not ready for war unless the engineering department can and does operate reliably and economically. It is, therefore, important that engineering personnel not only maintain their plant in a reliable operating condition, but also operate the entire engineering plant at maximum efficiency. Reduced appropriations during peacetime require every economy that will further the reduction of operating and maintenance costs. It should be remembered that the primary purposes of peacetime operation of naval ships are to indoctrinate, train, and prepare ship's crews for wartime conditions and operations.

The operation of engineering plants becomes unreliable when machinery derangements are of frequent occurrence. Certain types of derangements are caused by changing the set-up of the plant at high speeds, prolonged operations at high speeds, or radical maneuvering of the ship. But for the most part, malfunctioning of the machinery and improper operation of piping systems reflect inexperience or improper training of personnel, and can be traced to one or more of the following causes: lack of, or improper, inspec-

tions; inattentive watch standing; insufficient training; poor supervision; or nonestablishment of responsibility.

Accurate knowledge and continuous painstaking effort are required to keep engineering plants functioning at peak efficiency. To accomplish the latter, it is necessary to be familiar with chapter 41 of BuShips *Manual;* with applicable sections of BuShips *Journal;* with the various manufacturers' instruction books; and with official publications or directives on operational procedures and material upkeep.

When under way, the MM1 or C will normally stand watch as the senior petty officer in charge of an engineroom. The MM2, from his previous study and experience, should be capable of operating any individual unit of machinery, equipment, or piping system. As the senior watch stander, the MM1 or C must be capable of supervising all the operations of propulsion and auxiliary machinery, including the associated piping systems that are applicable to his watch station. In addition, the senior watch stander must also be alert to the over-all operation of the entire propulsion plant, which includes the other engineroom(s) and the firerooms.

The associated engineroom and fireroom are generally operated together as one propulsion unit. On some auxiliary ships this one unit may constitute the entire propulsion plant, whereas, on combatant ships, this unit may be one of two or four separate propulsion plants. To obtain maximum reliability and economy, the associated engineroom and fireroom must be operated together as one basic unit or engineering plant. The physical characteristics of compartments and bulkheads, or the location of machinery and equipment, have nothing to do with the operating principles of a propulsion plant. To overcome the difficulties of operating two separate spaces as one basic plant is one reason for BuShips changing the arrangement on large ships being designed and built. The new arrangement will have the basic propulsion plant, consisting of the major units of machinery and equipment of the associated engineroom and fireroom, in one engineering compartment.

In operating the associated engineroom and fireroom as

one complete propulsion plant, maximum reliability and efficiency cannot be obtained unless there is cooperation, understanding, and teamwork between engineroom and fireroom personnel. A great deal depends upon the knowledge and supervisory ability of the senior watch stander in each engineering space. The MM1 or C in charge of the engineroom should have a practical knowledge of fireroom operation, of safety precautions, and of the casualties that may occur during operation of the engineering plant.

On destroyers, on many auxiliary ships, and on small ships, the MMC in charge of the control engineroom will also be in charge of the entire engineering plant. On a ship where there is no engineering officer on watch, the MMC in charge of the control engineroom will assume the duties of the engineering officer of the watch. In this case, the MMC should have a good understanding of the routine procedures and regulations concerning the operation of the ship's propulsion plant.

The MMC in charge should see that the officer of the deck (OOD) and the engineer officer are immediately informed of all pertinent facts concerning the operation of the main engines. He should have a good understanding of the effect of all types of engineering casualties on the operation of the propulsion plant. He should also be capable of carrying out appropriate engineering casualty control procedures for the over-all operation of the propulsion plant. In other words, such action as placing standby machinery in operation, cross-connecting piping systems, or reducing ship's speed, should be taken when a casualty occurs to an individual unit of machinery or equipment. The individual casualty will be handled by the assigned operating personnel, whereas the MMC in charge of the engineering plant will take such steps as may be necessary to minimize the effect of the casualty on the over-all operation of the plant.

## EVALUATION OF ENGINEERING PERFORMANCE

During peacetime conditions, the objective of engineering training in the fleet is to create and maintain readiness to

deliver the designed performance of the engineering plant at all times. Such readiness includes the ability to operate free of breakdowns, to control engineering damage, to make prompt and effective emergency repairs, and to operate the engineering plant safely and economically. Administrative instructions are provided each ship for the purpose of furnishing a general and uniform guide by which type commanders, or their subordinates, may estimate or evaluate the engineering performance and readiness of the ships assigned to their command.

### Engineering Reliability

A ship must be capable of performing any duty assigned. Reliability is indicated by a ship's maintaining its scheduled operations and being in a position to accept unscheduled tasks. In order to do this, her machinery must be kept in good condition so that the various units will operate as designed, and the ship must operate in accordance with good practice and procedures. Some of the steps to promote reliability are:

1. A good preventive maintenance program should be carried out at all times. This involves timely inspections, tests, and repairs.

2. Machinery, equipment, and piping systems must be operated in accordance with good engineering practice. Operating instructions and safety precautions should be posted for each major unit for other units as considered necessary.

3. Supervisory personnel must have a thorough knowledge of the ship's machinery. Information on construction, operation, maintenance, and repair of machinery can be obtained from the manufacturer's instruction books and plans.

4. A good engineering department administrative organization will ensure proper assignment of duties and responsibilities, and proper training and supervision of personnel. The MMC, and in many cases the MM1, will have administrative and supervisory duties. As a supervisor, the MMC

(or MM1) should see that all pertinent instructions and routine procedures are carried out in regard to the proper operation, maintenance, and repair of machinery and equipment.

5. Personnel must be thoroughly trained. This can best be accomplished by a combination of several different methods of training. The primary and most effective method of training is learning by doing; a good example of this is watch standing. Another method of training is carried out by regularly scheduled and carefully planned instruction periods. Instruction periods are not limited to classroom instruction—they may take any form, such as holding engineering casualty control drills at scheduled periods while under way.

### Engineering Plant Economy

In order to obtain economy, the engineering plant while meeting prescribed requirements must also be operated so as to use a minimum amount of fuel. The FUEL PERFORMANCE RATIOS are indicative of the condition of the engineering plant and the efficiency of operating personnel. The fuel performance ratio is the numerical comparison of the amount of fuel oil used to the amount of fuel oil allowed for a certain speed or steaming condition. In evaluating engineering readiness, the fuel oil performance ratios reported on the Monthly Summary will be considered to indicate, in a general way, the prospective readiness of a ship to operate economically and within established logistic standards. In determining the economy of a ship's engineering plant, the same consideration is given to the amount of water used on board ship. Water consumption is considered as the gallons of make-up feed per mile, make-up feed per hour (at anchor), and potable water per man per day.

The improvement in a ship's fuel economy depends largely upon the careful operation of the various plant units which consume power. This further depends upon the complete understanding of the function and the features of each unit;

the plant set-up, which involves each unit in combination with other units; and the plant as a whole.

Concerning any measures which may be taken in the pursuance of fuel economy, there should be no violation of good engineering practice or of safe operation of the engineering plant. The health and comfort of personnel should not be reduced below the usual and expected standards.

Indoctrination of the ship's crew in methods used to conserve water is of the utmost importance, and should be given constant consideration aboard ship.

### Trial Performance

Trial performances, such as full power and economy trials, furnish positive evidence of a ship's engineering plant readiness for wartime steaming conditions. Although trial performances may vary under different conditions, they give evidence of a ship's readiness to make the required speed and also give an indication of the ship's economical operation. Additional information concerning trials will be given in a later chapter of this training course.

### Control of Engineering Casualties

The ability to control engineering damage and make emergency repairs in time of war is measured by the performance as observed in battle problems, or in other training exercises, and in actual emergencies.

To judge the reliable and economical operation of a ship, it is necessary to first consider the ability of the ship's force (without undue outside assistance) to maintain and repair the ship's machinery and equipment. For true evaluation, however, due allowance must be made for service, age, and character of machinery installed, for the time and facilities allotted for maintenance and repair, and for experience and opportunity for the training of engineering personnel.

The battle problem is the major part of an operational readiness inspection. A detailed program of training and scheduled exercises, or drills, in engineering casualty control

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is necessary for the engineer's force to operate satisfactorily during an inspection. It is a fallacy to depend upon a few key men; all men should be trained so that smooth team work and reliable performance may be obtained.

Care must be taken not to neglect the training of engineering personnel on steaming watch stations. Outside of wartime conditions, most of the engineering casualities occur when personnel are on steaming watch stations. The MM1 or C in charge of the engineroom watch should check the training of personnel on watch and have a good understanding of their ability to stand watch and handle engineering casualties. When practicable, the senior watch stander should take such steps as may be necessary to instruct and supervise the men on watch.

## ENGINEERING EFFICIENCY

### Economy Versus Safety

Aboard naval ships, economical measures cannot be carried to extremes, because there are certain safety factors that must be given consideration. At best, the operation of a combatant ship is a compromise between economy and safety. Unless proper safety precautions are taken, reliability may be sacrificed; and in the operation of naval ships, reliability is one of the most important factors. Therefore, in trying to operate an engineering plant as economically as possible, do not overlook various safety factors and good engineering practice.

For example, it is not always practicable to operate naval ships at economical speeds. In order to have the ships ready for wartime conditions, it is necessary to carry out fleet maneuvers, and to have frequent tactical exercises aboard individual ships.

### Promoting Economical and Efficient Operation

However, there are many other factors that, if given proper consideration, will promote economical and efficient operation of the ship's engineering plant. Some of these

factors are: (1) maintaining steam pressure constant, (2) proper acceleration of the main engines, (3) maintaining high condenser vacuum, (4) guarding against excessive recirculation of condensate, (5) maintenance of proper insulation and lagging, (6) keeping the consumption of feed water and potable water within reasonable limits, and (7) conserving the use of electrical power.

KEEPING MAIN STEAM PRESSURE CONSTANT. In order to maintain steam pressure constant, superheated steam temperatures should be kept as close to the designed temperature as operating conditions permit. Great care must be taken in raising and lowering superheated steam temperatures; otherwise the result will be leaking main steam joints. Such leaks will result in loss of efficiency.

THE PROPER ACCELERATION OF THE MAIN ENGINES is an important factor in the economical operation of an engineering plant. A fast acceleration will not only interfere with the safe operation of boilers but will also result in a tremendous waste of fuel oil. It must be remembered that the Machinist's Mate in charge of an engineroom, or standing a throttle watch, can contribute a great deal to the economical operation of the boilers.

Except for acceleration, or deceleration, and the operation of the main condenser, there are not many major factors to be considered in the economical operation of main turbines. On destroyers and other ships provided with cruising turbines these turbines should be used when operating conditions will permit. Turbine gland sealing steam should be properly maintained. Shaft packing, nozzle control valves, etc., should be maintained in good condition. When spinning main engines, care should be taken not to use excessive amounts of steam.

MAINTAINING HIGH CONDENSER VACUUM. The operation and proper maintenance of main condensers is also an important factor in obtaining maximum engineering efficiency. A low exhaust pressure (high vacuum) permits a greater range of expansion for the steam, thus making a greater number of British thermal units (Btu) per pound of steam available for

useful work. The total available energy in the steam is much higher per pound of pressure difference in the lower range of pressures than in the upper range. This is the most important reason why the condenser vacuum should be maintained as high as possible and in accordance with designed requirements.

The necessity for constant care and attention to prevent and detect air leaks, and the proper operation of the condensing equipment, can hardly be overemphasized.

GUARDING AGAINST EXCESSIVE RECIRCULATION OF CONDENSATE. The excessive recirculation of condensate should be avoided, as it will cool the condensate to an uneconomical degree. The use and the operation of the thermostatically controlled recirculating valve (discussed in chapter 4 of this training course) should be well understood.

MAINTENANCE OF PROPER INSULATION AND LAGGING. In every power plant there is a heat loss from all heated surfaces, and a heat flow to the surrounding air and cooler objects. This heat transfer should be kept to a minimum by proper insulation. Poor insulation (or no insulation) on steam machinery, valves, small lines, and sections of piping indicates a lack of understanding of the basic requirements of insulation.

While increasing the economy of the plant, insulation also reduces the quantity of air necessary for ventilating and cooling requirements. Proper insulation will also reduce the danger of personnel receiving burns from contact with the hot parts of valves and machinery. Good insulation, elimination of all steam leaks, and a clean ventilation system contribute a great deal to good economy and to habitable conditions in the engineroom.

CONSERVATION OF FEED WATER AND POTABLE WATER. Aboard ship, feed water and potable water consumption rates are entered on the Monthly Summary. A type commander judges the engineering efficiency of all ships operating under his command by referring to fresh water rates and fuel oil rates. For example, destroyers should normally use 10 to 14 gallons of feed water per mile under way, and from 100

to 120 gallons of feed water per hour when not under way.

Ships having excessive feed water consumption rates should undertake immediate and intensive campaigns to eliminate all water, steam, and drain leaks that contribute to the uneconomical operation of the individual plants. This program will not only improve feed water rates, but will also improve the fuel oil performance ratio.

The consumption of potable water by the ship's crew bears a direct relationship to efficient operation of the engineering plant; the greater the amount of fresh water distilled, the greater the amount of steam consumed. Conservation of fresh water requires the close cooperation of all personnel aboard ship, since large amounts may be wasted by improper operation of the laundry, scullery, or galley. Maintenance personnel should take prompt action to eliminate plumbing leaks.

Conserving the Use of Electrical Power. Excessive use of electric lights throughout the ship is a common source of waste of power. Lights are frequently left on when not needed, and in addition there is a tendency on the part of ship's personnel to use bulbs of a wattage greater than that authorized.

If the ship's ventilation system is improperly operated and maintained, the result may well be a waste of electric power. Continued high-speed operation of vent sets adds to the electrical load on ship's service generators. Dirty and partially clogged ventilation screens, heaters, cooling units, and ducts will result in inefficient operation and power loss.

In checking the operation of the engineering plant for efficiency, it is important to consider proper operation and maintenance of the various units of auxiliary machinery. Economical operation of the distilling and the refrigeration plants, and of the air compressors, will contribute a great deal to over-all efficiency. Because of the large number and various types of pumps aboard ship, their operation and their maintenance are important factors. Auxiliaries that operate continuously, or most of the time, must be given

very careful attention with respect to efficient operation and required maintenance.

**Recommendations for Efficient Operation.** Whenever the smooth and continuous operation of the propulsion plant is disrupted by casualties, a loss in economy will result. The following are some specific recommendations for the efficient operation of engineering plants:

1. Use the minimum number of forced draft blowers. It is more economical to run one blower near its designed full speed than to run two blowers at a lower speed.

2. Do not operate with excessive feed water pressures. Excessive pressure results in a waste of feed pump power.

3. Maintain the proper fuel oil temperature. Do not operate more fuel oil heater units than necessary for proper heating. Overheated fuel oil not only wastes steam, but also fouls the heaters.

4. Maintain the superheated steam temperature as close to the designed temperature as operating conditions of the ship will safely permit.

5. Steam with a light brown haze, whenever permissible. The clean stack condition between the light brown haze and the white smoke indicates that the percent of excess air ranges from 20 to 200 percent. The ideal point is that narrow range from haze to just clear.

6. Boiler casings should always be tight. Leaky casings indicate excessive fuel consumption.

7. High feed water consumption indicates an uneconomical plant. No leak is so small as to justify neglect.

8. Clean the boiler tubes regularly. Soot and scale are insulators which prevent heat transfer. Dirty boilers indicate high and uneconomical fuel rates.

9. Blow the tubes in steaming boilers at least twice each day at sea, and at least once each day when steaming for auxiliary purposes. Also blow the tubes before securing the boilers.

10. While steaming, blow the boilers down at reasonable periods, to avoid high concentrations of scale-forming salts in the boiler water.

11. Maintain proper fuel combustion in a boiler furnace. Poor combustion results in a large decrease in efficiency.

12. Keep the steam pressure and temperature as steady as practicable at all times.

13. Throttlemen should carefully follow the standard acceleration table posted on the throttle board. Fast accelerations result in waste of fuel oil.

14. Check the condensing systems frequently for proper operation and tightness.

15. Avoid excessive recirculation of the condensate.

16. Steam at the ship's most economical speed, whenever permissible.

17. Feed water in the deaerating feed tank should be properly heated and deaerated.

18. Check all drain lines and steam traps for good material conditions and proper operation.

19. All orifice plates in piping systems should be checked for good material condition and proper operation.

20. Keep the steam pressure to the air ejectors steady and at the designated pressure.

21. Maintain the thermostatically controlled recirculating valve in good condition and operate it under proper conditions.

22. Maintain the auxiliary exhaust system and the associated automatic valves in good condition.

23. Follow the proper procedures in taking on make-up feed water.

24. Maintain all heat insulation and lagging in good condition. Remember that painted surfaces will reflect heat, and that black, or dark, surfaces will absorb heat.

25. Keep the bilges dry. Water in the bilges will add to the humidity of the air, necessitating more ventilation to keep the space habitable.

26. Keep ventilation systems, especially for engineering spaces, clean at all times.

27. Ventilation motors should be run on low speed, unless high speeds are necessary because of hot weather or hot compartments.

28. It is more economical to operate one ship's service generator at full load than two generators at very light loads. Whenever the ship's safety and the electrical loads will permit, one generator, rather than two, should be operated.

29. Maintain proper lubricating oil temperatures. Cold lubricating oil can be an indirect cause of excess fuel oil consumption.

30. Use the proper set-up of pumps to feed steaming boilers.

31. Check on the efficient operation of heat exchangers for auxiliaries.

32. Check the condensate depression of the main condenser, when in cold waters.

33. A careful routine should be carried out when checking for water in the fuel oil. Burning fuel contaminated with salt water is very uneconomical, and may disrupt the engineering plant.

## STEAMING ORDERS

The procedure of getting a ship under way, especially a large ship, in a smooth and efficient manner depends to a great extent upon the administrative procedures and organization of the engineering department. The posting of the steaming watch, the advanced supply of necessary information to supervisory personnel, the dissemination of instructions to watch standers, the mustering and checking of watch standers on stations, and the lighting off of the main plant and standing by to get under way, involve certain procedures, coordination, and instructions by supervisory personnel.

To prevent misunderstanding and confusion, forms and check-off lists are used for getting a ship under way. The purpose of check-off sheets for lighting off, or securing, the main plant is to provide a convenient and simple procedure by checking the required steps in a proper sequence. Check-off lists will ensure that no important steps have been overlooked, or momentarily forgotten. Steaming orders are necessary, especially on large ships, to supply advanced in-

formation to supervisory personnel, and to enable administrative personnel to make the necessary preparations. On small ships and in the M division on large ships, an MM1 or C will carry out many supervisory duties and responsibilities.

On the steaming orders form are listed the various machinery units and readiness requirements of the engineering department; these are based upon the time set for getting under way. This form generally includes the major machinery to be used, the lighting-off times, the cutting-in of boilers and spinning of propulsion turbines, the cutting-in of ship's service generators, the standard speed, and the names of the engineering officer and the leading petty officer of the watch. The early posting of such orders is essential in getting a large propulsion plant under way with a minimum of confusion.

On smaller ships, such as destroyers, steaming orders are usually brief and simplified. The first part of an engineroom lighting-off sheet is generally used as the steaming orders. Key supervisory personnel, such as the MMC, BTC, and EMC, are notified by the engineer officer, or by the assistant engineering officer, as to the time the ship will get under way. The duty MMC, who has received all the necessary information and instructions, is responsible for making preparations to get the ship under way.

## GETTING THE PROPULSION PLANT STARTED

When all watch standers have mustered in the engineroom, the MM1 or C in charge of the engineroom watch should inform the main engine control that his engineroom is manned and ready to light off. The MMC in the control engineroom, especially on smaller ships, should check to see that all engineering spaces are manned and ready to light off. He should also see that all other reports, as required in the lighting-off procedure, are made to the control engineroom. It must be remembered that the control engineroom should take precautionary measures to ensure that all stations have been manned by the steaming watch.

A general check-off sheet, or table of instructions, to be followed in getting the propulsion plant started is usually provided on each ship. These instructions will differ in accordance with the installation and the desires of the engineer officer. The following warming-up schedule is a typical example of that used for propulsion plants aboard destroyers.

ENGINEROOM WARMING-UP SCHEDULE

| *Time Allowed* | *Operation* |
|---|---|
| 01—45 | Station the engineroom steaming watch. Take and record the counter reading and turbine clearances. Enter them in the log, specifying that they are cold readings. Prepare Operating Records and Bell Book Sheets. |
| | EM energize circuits to all necessary motor-driven pumps and IC circuits. |
| | Open all funnel drains wide. Close when steam blows through, and shift to high-pressure drain line. Cross-connect feed water drain collecting tanks. |
| | Line up the high-pressure drain line to the deaerating feed tank. Crack the bypass on the drain discharge (where installed). Line up the fuel oil heating coil drains to the inspection tanks. |
| | Back off all throttles, throttle the bypass and nozzle valves, and reseat lightly by hand. Check to see that all turbine drains are open. Test engine "wrong-direction" alarms. |
| | Open the bulkhead stop valves, the crossover valves, and the line stop valves for boilers to be cut in on the main steam line. The fireroom should then crack the bypass on the steaming boiler's stop valve, and slowly build up pressure on the main steam line. |
| | Cross-connect the auxiliary steam lines; also, the exhaust lines. |
| 01—30 | Clean the lube oil and the bilge strainers. |
| | Check oil levels in the sump tanks, pumps, oil sumps, and main spring bearing oil sumps. |
| | Check the temperature of the main lube oil sump tanks. If it is below 90° F, warm up by means of purifier heaters, or connect the steam hose to the cooler, and heat the oil. Ensure that |

| *Time Allowed* | *Operation* |
|---|---|
| | the coolers are full of water, and that the lube oil cooler vents are open. |
| | Start a main lube oil pump in each engineroom, and check: oil delivery to all bearings, lube oil low-pressure alarm settings, leaks, opening of main lube oil governor valves (where installed), and operating levels of main engine sump tanks. |
| | Slack off stern-tube glands, allowing a small amount of water to leak through the gland. |
| | Engage the jacking gears and start jacking over the main engines. Display suitable signs at the main throttle valves. |
| | Check the flushing main set-up and line-up of the cooling service main. Check the cooling systems of auxiliaries. |
| 01—00------------- | Open the main condenser injection, overboard, and salt-water side vent valves. Start the main circulating water pumps. Do not operate with less than 125–150 psi steam chest pressure. |
| | Line up the gland exhauster condensers. Start the main condensate pumps. Recirculate condensate through the air ejectors back to the main condensers. |
| 00—50------------- | Cut in steam to the main turbine glands. Bring up the main condenser vacuum slowly by cutting in steam to the second stages of the main air ejectors. Check gland leak-off's to ensure that they are properly lined up. Start the gland exhauster fans. |
| | Warm up one main feed pump in the engineroom having the hot deaerating feed tank. Cool the emergency feed pump for 15 minutes before obtaining cold suction. |
| | Warm up the idle deaerating feed tank. Start the main feed booster pump and open wide its recirculating valve to the deaerating feed tank. |
| 00—45------------- | Test the engine-order and engine-revolution indicator systems, verifying via telephone each position on the bridge and in each engineroom and fireroom. |
| | Cut in steam to the whistle and to the siren, slowly. When the lines are completely |

| *Time Allowed* | *Operation* |
| --- | --- |
| | drained by the bypass traps, cut in the traps and secure the bypasses. |
| | When the vacuum on the main condenser reaches 20 inches, shift the auxiliary exhaust to the main condenser. Shift drains to the main condenser. |
| | Start the second ship's service generator. When it has been thoroughly warmed up, put it on the line. |
| | Test the low pressure oil alarm. |
| 00—30 | EM's, in conjunction with deck operators, test the anchor and steering engines. Results of the tests are to be reported to the forward engineroom. |
| | Request permission to test the main engines at 0–15 minutes "schedule" time. |
| | In each engineroom, cut in the first main feed pump on the main feed line, and warm up the second main feed pump. |
| 00—20 | Warm up and test out the standby auxiliaries (include lube oil shaft pumps, feed booster pumps and condensate pumps). |
| | When steam pressure has equalized on the main steam line, open the main boiler steam stop valves ½ travel. |
| | Cut in steam to the first stage to the main air ejectors, and bring up the vacuum to approximately 29 in. |
| | Put the No. 2 boiler on the main and the auxiliary steam lines when the steam pressure is up to the line pressure. Open the main stop valves only ½ travel. Cut in the second main feed pump. |
| 00—15 | Man 1JV and 2JV phones in all main machinery spaces. Ensure that the bridge and the main deck (aft) phones are also manned. |
| | When permission has been granted to test the main engines, notify all main machinery spaces to stand by. Station observers on each shaft. Disengage the jacking gears. Spin the shafts in opposite directions, as directed by the engineering officer of the watch, ensuring that no way is put on the ship. |
| | Open wide all the main and boiler stop valves. |

| *Time Allowed* | *Operation* |
|---|---|
| | When all the main machinery spaces report ready, the engineer officer should notify the bridge that the engineering department is ready to answer all bells. Ensure that standard speed is known to all main machinery spaces. |
| While standing by--- | Take and log main turbine axial "hot clearances," specifying hot readings. |
| | Spin the main engines by steam every three minutes, ensuring that no way is put on the ship. |
| 00—00------------- | Under way when ordered. Notify the after engineroom and both firerooms. Log the counter readings. |
| 00—05------------- | Secure the main turbine drains. |

NOTES

1. The plant should be fully split at all times when the ship is leaving port or maneuvering in restricted waters.
2. When directed, set the split-plant condition prior to testing the main engines.
3. Split the plant when ordered and check the following systems:
   a. Main steam line
   b. Auxiliary steam line
   c. Auxiliary exhaust
   d. High-pressure drains
   e. Low-pressure drains
   f. Condensate pump discharge cross-connection
   g. Booster pump discharge cross-connection
   h. Main feed pump cross-connection
   i. Auxiliary feed pump cold suction and transfer line
   j. Salt water flushing system
   k. Generator a-c and d-c loads
4. Submit the completed form to the engineering department by the end of the first watch.

## FIREROOM OPERATIONS

In order for an MM1 or C to carry out his duties properly, he must possess some knowledge of the basic fireroom procedures. This is especially true on those installations where an MMC is in charge of the control engineroom while under way. The efficient and safe operation of the engineering plant depends to a large degree on the close cooperation

between the fireroom and engineroom personnel. This close cooperation will, in turn, depend upon the MM's knowledge of the fireroom and the BT's knowledge of the engineroom. By the time personnel in either space have become first class or chief petty officers, they should have an excellent understanding of the entire engineering plant. This does not mean they should be able to switch watch-standing jobs, but they should know what is occurring on the other side of the bulkhead or, as the case may be, on the other side of the space.

Close cooperation between the spaces is most important when lighting off or securing the plant. As additional machinery is started in the fireroom, the engineroom should be notified. In many cases, the fireroom should be notified as machinery is stopped, or started, in the engineroom. These matters should not be taken for granted; it should not be assumed that personnel in the other space know which machinery is in operation. In the case of feed pumps, for example, personnel in both spaces should know at all times which feed pumps are in operation, and which pumps are standby.

It is essential that the MM1 or C have a knowledge of the fireroom lighting-off procedures and the time required for the fireroom to be ready for getting under way. The machinery should not be required or expected to be put into use before the proper warming up time has elapsed.

## Types of Boilers

There are several makes and classifications of boilers in use today. However, with few exceptions, all propulsion boilers are equipped with superheaters. Superheated boilers are further classified as to whether or not the superheater outlet temperature is controllable.

The TWO-FURNACE SINGLE-UPTAKE SUPERHEAT-CONTROL BOILER is installed in destroyers, cruisers, battleships, and larger carriers. The operating pressure of this type of boiler is 600 psi with a maximum superheater outlet temperature

of 850° F. The superheaters of these boilers cannot be fired unless the safe minimum flow of steam is passing through the superheater; when the boilers are operating at full steam temperature, the safe minimum steam flow varies from approximately 5000 to 9000 pounds per hour (depending upon the type and size of the boiler in question).

On large combat installations, there is usually sufficient steam flow (even when steaming for auxiliary purposes) to maintain light fires on the superheater side. However, in some cases and particularly in the case of destroyer installations, it is usually necessary for the ship to be under way and making about 12 knots before the superheater can be placed into operation. Also, whenever the superheater is operating and the steam flow drops below the minimum, the fires under the superheater must be secured immediately. On destroyers, the superheater fires must usually be secured when the speed of the ship drops below 10 knots. From the standpoint of maintenance and repairs to the steam piping, turbine casings, and superheater handhole plates, it is not profitable to put the superheater into operation until it is expected that, for a considerable period of time, the ship's speed will be greater than 10 knots. In addition, continually lighting off and securing the superheater will cause extensive steam leaks throughout the parts of the system subject to fast-changing temperature conditions. These steam leaks will waste more fuel than would ever be saved by the few minutes of superheat operation.

THE NO CONTROL, INTEGRAL SUPERHEATER BOILER (not separately fired) creates a different type of problem. During operation, there is no problem since all steam passes through a superheater and is superheated. After the boiler is on the line and furnishes steam, there will be a sufficient flow because all the steam generated passes through the superheater.

However, when lighting off and securing, there is no normal flow of steam through the superheater and some means of flow must be established. This means that before a boiler is cut in, and after it is removed from the line, cooling steam must pass through the superheater.

A brief discussion on the construction and operation of the no control superheat boiler will help you to understand the need for protection steam during lighting off and securing operations.

The superheater is installed within the banks of the generating tubes and receives heat from the same fire as the generating tubes. In operation, the steam is generated and before any of it is used, it is routed through the superheater. The steam used for auxiliary purposes must be desuperheated by passing it through a desuperheater that is submerged below the water level in the steam drum. When the boiler is steaming for auxiliary or underway purposes, there is a constant flow of steam through the superheater sufficient to cool the superheater tubes. However, during the time when the boiler is lighted off (before the stops are opened), and when the boiler is being secured (after the stops are closed), there is no normal flow through the superheater. Of course, during these periods there is heat in the furnace and the superheater tubes are subjected to this heat. If steam is not passed through the superheater during these periods, the superheater will become overheated and suffer damage. This problem is overcome by piping steam from the auxiliary steam line, through the superheater and into the auxiliary exhaust line.

The no control superheat boiler is installed on DE's, on auxiliary ships, and on some carriers. The operating pressure range of these boilers is from 400 to 460 psi. The superheater outlet temperature usually varies from approximately 700° to 775° F.

### Lighting Off the Fireroom

It takes from 1 to 2 hours to raise steam to full pressure in the boilers. If the boiler has not been steamed for a period of time and is completely cold, the longer period of time will be required.

When lighting off, the firerooms and the enginerooms must be manned. When additional steam machinery is to be started, the engineroom watch must be notified.

As additional machinery is started in the spaces, the load

on the steaming boiler is proportionally increased. Of course this does not burden the boiler; however, where a reciprocating emergency feed pump is used to feed the in-port boiler, an undue load is placed on this pump. The reciprocating emergency feed pump is not designed to feed the boiler constantly under any other than low load or in-port conditions.

It is of primary importance that these type pumps be maintained at peak operating condition, as they have more than once saved the day by maintaining the water level for short periods when the main pumps failed. The larger pumps should, as soon as possible, take the load when lighting off. They should also be kept in operation after the plant is secured, until such time as the load on the in-port boiler has dropped to near normal.

The following procedure should be used when lighting off a destroyer boiler:

1. Remove the smoke-pipe cover.
2. Inspect and clean all strainers.
3. Clean all atomizers. Place them in the air registers for adjustment with reference to the diffusers, then remove all the atomizers except those to be used in lighting off. Test out the working of the air registers.
4. Close the individual atomizer root and needle valves.
5. Steam or wash out all bilges.
6. Inspect the bottoms and inner fronts of the air casings of all air-encased boilers to see that they are clear of any oil accumulations or drip; clean out any oil accumulation and correct drips, if noted, prior to lighting off.
7. Wipe up all oil on floor plates and elsewhere.
8. Inspect for and remedy oil leaks.
9. Make certain that the inner casing drain holes of the double front burners are open and clear for conducting any atomizer drip to the furnace.
10. Examine all casing doors to ensure that they are closed and airtight.
11. Open the air cocks, including the air vents on the superheater; open the superheater drain to the bilges.

12. Open the water gage shut-off valves.

13. Drain the boiler to the bottom of the 10-in. glass, if the boiler has been idle.

14. Cut in the auxiliary steam and exhaust lines; open the necessary drains.

15. Examine the hand gear for lifting the safety valves and operate this gear, so far as can be done, without lifting the safety valves.

16. Raise the water level in the boiler to about two inches in the 10-in. glass, by opening the main feed check and stop valves to ensure that these valves are functioning properly, and that the economizer is filled.

17. Ease up the boiler main steam stop valve stems without lifting the valve disks off their seats with the deck control gear, so as to prevent sticking when the valve heats up. Where double valve protection is installed, first open the valve next to the boiler. Then handle the second valve with the bypass. This applies to auxiliary as well as to main stop valves.

18. Open all cocks and valves in the line to the boiler steam gage.

19. Line up the fuel oil suction and discharge lines.

20. Drain and start one forced draft blower and blow out the furnace. Ensure that shutters on the idle blower are in the closed position to prevent it from rotating in reverse direction and suffering damage because of lack of lubrication.

21. Drain and start the fuel oil service pump (or the electric pump).

22. Cut in the fuel heater and circulate oil through the heater and burner manifold until oil reaches the proper temperature for atomization (about 135°–140° F.). Bypass the meter during recirculation.

23. EM's energize the thermal alarm of the superheater, and test.

24. Close all registers except No. 1.

25. Cut in the fuel oil meter.

26. Push all the way in, and light off the No. 1 atomizer,

using the 5015 sprayer plate; use a torch and stand well clear to avoid flareback.

27. At no time while raising steam in a boiler, and prior to cutting it in on the main steam line, should a burner be lighted under the superheater side except on the specific orders of the engineer officer. No superheater burners should be lighted unless the superheater protection device indicates a safe steam flow through the superheaters.

28. Warm up the additional fuel oil service pump.

29. As the boiler heats up and steam forms, frequently check the water level for rise in glass.

30. Close all air cocks and vents after steam has formed and all air has been expelled.

31. Warm up the emergency feed pump and line up suction and discharge.

32. Check the boiler gage to see that it at once registers pressure.

33. When boiler pressure reaches approximately 50 to 75 psi, close the superheater bilge drains and cut in the high-pressure drains.

34. Start warming up the main steam line, using bypasses, and open the drains.

35. Lift the safety valves by hand when the boiler pressure is 100 psi below the reseating pressure of the safety valves. Prior to lifting the safety valves, test the superheater for presence of condensate, by use of the drain to the bilges.

36. Check the operation of the gage glasses by blowing them through.

37. With the boiler pressure slightly above the line pressure, cut in on the auxiliary steam line, then on the main steam line when ordered by the control engineroom, cracking superheater outlet valve slowly; when pressures have equalized, open both valves wide. (The turbogenerator steam line on DD445 and 692 classes should be opened.)

38. Commence feeding the boiler.

39. Put in place a set of maneuvering-size sprayer plates.

40. Warm up and start an additional forced draft blower.

41. Report ready to get under way.

After a ship is under way, light fires under superheaters when ordered by the control engineroom, provided the flow meters register sufficient steam flow. THE SUPERHEAT SHOULD BE RAISED EVENLY ON ALL BOILERS, AT THE RATE OF 50° F EVERY 5 MINUTES.

## Paralleling Boilers

It is sometimes necessary to light off and put additional boilers on the line, after a ship is under way. With saturated or no control superheater boilers, the steps are much the same as when putting the first boiler or boilers on the line. However, with superheat control boilers and with the superheaters of steaming boilers in operation, additional precautions must be taken.

When the steam lines are carrying superheated steam, it would be dangerous to admit saturated steam therein. In most cases, it is not normally possible to establish enough steam flow to light off the superheaters of the incoming boilers until they are on the main line. It is permissible, however, to cut in the incoming boilers, without their superheaters in operation, if the temperature of the steam in the lines is lowered to 600° F. Such lowering of the operating temperature should be started in ample time so that the cutting-in temperature can be reached when the incoming boilers are up to pressure. Except in an emergency, the temperature should not be lowered or raised at a faster rate than 50° F every 5 minutes.

If the ship is operating at a speed that requires the maximum temperature and the saturated furnaces are being fired at the maximum design rate, this lowering of temperature will mean that the speed must be reduced. If an emergency exists, it is permissible to attempt to establish flow on the incoming boilers by (1) opening the superheater bilge drains, (2) opening the main steam line low-pressure drains, (3) opening the main stop bypasses, and (4) steaming the boilers directly to the idling generators. If such measures succeed in establishing sufficient flow, the superheaters may be lighted

off and the temperature brought up before the boilers are cut in on the main line. However, it is to be reemphasized that these measures may be attempted only in *cases of extreme emergency.*

With regard to superheater operation, the casing air pressure is a very important factor. When it is known that superheaters are to be put into use, they should be lighted off before the saturated furnaces are being fired at a high rate. It is extremely difficult to insert a lighted torch in the superheater furnace when the air casing pressure is high. The torch will almost invariably be blown out before the superheater burner can be lighted. During such operations, injury to personnel has resulted from flareback. In brief, superheaters cannot be lighted off when saturated firing rates and steam flow are extremely low, and they should be lighted off before the firing rates are extremely high.

### Securing Procedures

Prior to entering port and securing, orders should be given to the fireroom to blow the boiler tubes. If the Boilerman on watch does not initiate such a request, the engineroom watch should do so, and when permission is received from the bridge the word should be relayed to the firerooms.

During securing operations, close coordination between spaces is important. This applies particularly to the fireroom and engineroom that remain lighted off for in-port steaming. When the feed pump operation is switched from one space to another, the pump being placed in service must have the load before the one in operation is secured. The pump to be secured should be allowed to remain in standby status until it is certain that the other pump has the load.

Reciprocating emergency pumps should not be put in operation if the deaerating feed tank temperature is excessive. The packing in these pumps cannot long withstand temperatures in excess of those for which they were designed.

When securing the firerooms and enginerooms, most personnel have a tendency to rush. This is a serious mistake

which should not be made. Hurried securing operations can result in a loss of the load.

The following table lists the steps for securing the boilers on a destroyer:

1. When permission has been received from the OOD, blow the tubes with soot blowers.

2. Close the oil valves to the atomizers one by one, superheated side first, at the same time closing the air registers.

3. Slow down the oil service pump as the atomizers are shut off, to prevent the pressure from building up.

4. Remove the atomizers promptly on securing, and drain the contained oil into a closed bucket; remove the plates and tips, and keep them in kerosene or Diesel oil until they can be cleaned and oiled.

5. Shut off the steam to the oil heater to prevent excessive heating and carbonizing of the oil as the flow is reduced.

6. Slow down the forced draft blowers.

7. When all atomizers are closed, secure the oil lines and the oil pump.

8. With registers slightly cracked, run a blower just long enough after shutting off the oil supply to ensure that all oil on the furnace floor is consumed and that the furnace is cleared of all gases, and to prevent overheating of burner parts adjacent to the furnace.

9. Close up the furnace tightly to prevent access of cool air into the heated interior, as sudden cooling-off will cause serious damage to the refractory lining and may cause warping of tubes.

10. Close the main superheater outlet and the line stop valves.

11. When the boiler ceases to require feed, close the auxiliary steam stops and fill the boiler to three-fourths glass.

12. When the boiler pressure reaches 50 psi, shift all drains to atmospheric.

13. Wipe up the oil on the floor plates, drip pans, etc.; clean the drain holes from the inner front to the furnace.

14. If practicable, put on smoke-pipe covers to prevent access of moisture into the uptakes and boiler firesides.

15. When the boiler has cooled, open the air cocks, fill the boiler completely with water, and see that the water is circulating. Then close the air cocks and pump to 50 psi hydrostatic pressure.

## COMING INTO PORT

After the control engineroom has been notified as to the time the ship will enter port, the necessary preparations should be made in advance for entering port and securing the main engines. Personnel should be informed and given specific instructions for setting up the auxiliary steaming watch in port. On most ships, especially on smaller ships, the MMC in charge of the watch will supervise the preparation for coming into port and the operations that take place. The MM1 and MMC will also be concerned with the administrative procedures involved in bringing a ship to anchor, securing the main engines, and setting the auxiliary steaming watch.

While the ship is still out in open sea, the control engineroom should request permission from the OOD to pump the bilges. In addition, a request should be made to blow the tubes on all steaming boilers. A report should be made to the bridge when the pumping of bilges and the blowing of tubes has been completed.

In some cases the ship will have fuel oil tanks ballasted with salt water. Care should be taken to see that all saltwater ballast has been pumped out before a ship enters port.

### Lowering the Superheat

The difference between the superheater outlet temperature and the saturated steam temperature is known as the DEGREE OF SUPERHEAT.

As mentioned before, it is necessary to lower the maximum temperature of the superheated steam (particularly on destroyers) prior to entering port or coming to anchor. The maximum steam temperature to be used in the ASTERN TURBINES of an installation having superheat control boilers varies from 675° F to 800° F. The use of superheated steam

in the astern turbines usually limits the rpm to be made and/or the time that astern operations can be safely conducted. Therefore, it is preferable that in-port maneuvering be done on saturated steam.

The lowering and/or securing of the superheat requires close cooperation between the OOD, the control engineroom, and the firerooms. This is especially true on destroyer installations, where extremely low maneuvering speeds usually require immediate securing of the superheaters. The firerooms must receive word in sufficient time so that the boilermen can lower the superheat at the prescribed rates. (Remember that superheat should not be lowered or raised at a greater rate than 50° F every 5 minutes).

The necessity for slowly lowering or raising the steam temperature can be readily understood when the following facts are considered:

1. The boiling point of water under a pressure of 600 psi gage is approximately 489° F. This will also be the temperature of the saturated steam rising from water boiled at that temperature.

2. There is usually a carry-over of heat from the saturated furnace to the superheater tubes, even when the superheater burners are secured. This gives the steam at the superheater outlet a slight degree of superheat (the total steam temperature usually reading 500° F, or slightly higher) with the superheat side secured. Thus, when operating at maximum superheater outlet temperature (850° F) there is a degree of superheat of approximately 350° F.

3. When the superheat side of a boiler is suddenly secured, the entire piping system, from the superheater to and including the turbine, is immediately subjected to a cold shock equivalent to 350° F less than what it was operating at. Repeated cold-shocking invariably results in leaks throughout the system. If these leaks are not corrected at once, the final result is that steam cuts cannot be corrected without extensive repairs.

4. When it is desired that the steam temperature be

lowered or raised, the firerooms should be notified in sufficient time so that the desired temperature can be reached slowly.

A thorough understanding of superheater operating procedures may be had by studying chapter 7 of Boilerman 1 and C, NavPers 10536–A.

### Auxiliary Machinery

On installations where the turbogenerators exhaust to either the auxiliary or main condensers, the following procedure should be used:

1. Put the auxiliary condenser in operation, and start the standby turbogenerator, allowing it to exhaust into the auxiliary condenser. In an emergency, this will permit the use of reserve electric power.
2. Shift the auxiliary exhaust to the auxiliary condenser so that the main plant can be secured in less time.
3. Warm up the auxiliary machinery which is to be used in anchoring the ship.

## SECURING THE PLANT

Each type of ship will have its own detailed forms for securing procedures. The following check-off list, which is that used on destroyers, is given as an example.

ENGINEROOM SECURING SCHEDULE

| *Time allowed* | *Operation* |
|---|---|
| | Pump all bilges, and contaminated oil and water tanks. Dump overboard all oily rags and trash. |
| | Obtain the OOD's permission to blow the tubes on all steaming boilers. |
| 00—30 | Set the split-plant condition, completely or partially as dictated by the fireroom set-up, and ordered by the engineer officer. |
| | Consult the engineer officer as to the following set-up for auxiliary purposes: boiler number, auxiliary engineroom, make-up feed suction and standby, fuel oil suction and standby, distilling plant operation and feed or potable water discharges, auxiliary watch section. |

| *Time allowed* | *Operation* |
|---|---|
| | Shift the deaerating feed tank vent to the auxiliary air ejector, if the tank is to be used for auxiliary purposes. Vent the tank to bilge if it is to be secured. |
| | Lower the superheat temperature slowly to 650° F. |
| | Have maneuvering burners standing by for use when the demand becomes imminent. |
| 00—15........ | Warm up the standby main feed pumps, the emergency feed pumps, and the main circulating pumps. Man the JV telephones, between the bridge and the control engineroom, and between the main machinery spaces in operation. |
| | Start the auxiliary plant; and, where piping arrangement permits, shift the ship's service generators to the auxiliary steam line. Cut out superheaters when the load indicates. Check the feed temperature; check the auxiliary exhaust pressure, and regulate if necessary. |
| | Check the operation of the main injection flapper valves when the main circulating pumps are started. |
| 00—10........ | Shift to the high-pressure turbine combination when the first bell is received. Crack the main and cruising turbine drains when the first stop bell is received. While stopped, spin the main engines by steam every three minutes, ensuring that no way is put on the ship. |
| 00—00........ | When the order to secure the main engines is received (via telephone) from the OOD:<br>a. Secure the main steam stop valves.<br>b. Secure the main and the cruising throttle valves and the crossover valves.<br>c. Engage the jacking gears and jack continuously. Tag out the throttle valves while the jacking gears are engaged.<br>d. Notify the fireroom(s) to secure excess boilers, and to close the boiler main stop valves. Bleed the boiler drum excess pressure via the auxiliary stop valves, and bleed the secured lines via the drains.<br>e. Secure the first stage of the main air ejectors.<br>f. Notify the fireroom to start the emergency feed pump(s) and secure the main feed pumps as soon as practicable. Ensure that the valve on the feed-booster recirculating line and the bypass to the |

thermostatically controlled condensate recirculating valve are open prior to securing each main feed pump. Secure one generator, if possible.

g. Secure steam to the whistle and to the siren.

h. Obtain permission of the OOD and secure steering gear and IC under way circuits.

00—10........ When the steam pressure on the main steam line drops to 50 psi, secure the high-pressure drains on this line, and bleed down to zero pressure via the open-funnel drains to the low-pressure drain line. Secure the bulkhead stops and the crossover valves on the main steam line.

00—15........ Secure steam to the main air ejectors and to the second stage nozzle valves. When the vacuum on the main condenser drops to 10 inches, secure the gland sealing steam, the gland exhaust blower, and the condenser. The evaporator watch should shift the first-effect coil drain.

00—20........ Shift to the electric lube oil pump (if installed).

Secure the main lube oil cooler when the oil temperature falls to 120° F. Cut in the cooler at intervals, as necessary, to maintain the oil temperature below 120° F.

00—30........ When the main air ejector inter- and after-condensers are cool, secure the main condensate pumps. However, if dehumidifiers are installed, condensate must be circulated until they have been secured. The dehumidifying units must be operated until the main reduction gear housing is within 10° F of the engineroom temperature.

When the main condenser cools to 90° F, secure the main circulating pump. Close the main injection and the overboard valves.

00—45........ Check and secure all necessary drains on the high-pressure and low-pressure drain lines. Close the steam piping root valves for auxiliaries, so that condensate will not collect in the piping sections.

Operate the lube oil purifiers not less than one hour, and as much longer as is necessary to separate out all the water.

01—00........ Secure all unused deck machinery, with permission of the OOD.

Wipe down all secured machinery and floor plates. Clean all strainers.

| *Time allowed* | *Operation* |
|---|---|
| | Stop jacking the main engines. Secure the main lube oil pumps. |
| 02–00 | Secure the stern-tube glands. |
| | Secure all unnecessary lights and vent blowers. |
| | Report the main engines secured to the engineer officer and the OOD. |
| 04–00 | If dehumidifying units are installed on the main reduction gear casings, the auxiliary watch should continue to operate them for a total of four hours after the main engines are ordered to be secured. Concurrently, condensate must be circulated. |

NOTES

1. When entering port or maneuvering in restricted waters, the plant should be fully split at all times.
2. When Special Sea Details are called away, the JV telephones must be manned immediately.
3. Send this completed from to the engineering department by the end of the first auxiliary watch after securing.

## SUMMARY

In order for the engineering department to function efficiently, the personnel concerned must maintain the ship's propulsion plant in a reliable condition, and must operate the entire plant at maximum efficiency. Machinery derangements may result from improper operation of equipment and/or machinery, lack of inspections, insufficient training, poor supervision, and inattentive watch standing.

For maximum reliability and economy aboard ship, the associated engineroom and fireroom must be operated together as one basic unit. In operating these spaces as one complete plant, the MM1 or C in charge of the engineroom must be familiar with fireroom operation, safety precautions, and casualties that apply to the operation of the engineering plant.

On a ship having no engineering officer on watch, the MMC in charge of the control engineroom assumes the duties of the engineering officer of the watch. Therefore, the MCC should possess a good understanding of the routine proce-

dures and regulations regarding the operation of the ship's propulsion plant.

Engineering reliability may be promoted by maintaining a ship's machinery in satisfactory condition and operating the ship in accordance with good practice and procedures. The improvement in a ship's fuel economy depends largely upon the careful operation of the various plant units which consume power. This, in turn, depends upon the complete understanding of both the function and the features of each unit, and the plant set-up involving each unit in combination with other units. All possible practical steps should be taken by the engineer's force to operate and maintain the engineering plant at maximum efficiency.

The early posting of steaming orders is essential in getting a propulsion plant under way with a minimum of confusion. Remember that the control engineroom should take precautionary measures to ensure that all stations have been manned by the steaming watch.

It should be noted that close cooperation between the engineroom and fireroom personnel is important when the plant is being lighted off or secured. The lowering and/or securing of the superheat requires close cooperation between the OOD, the control engineroom, and the fireroom; this is particularly true on destroyers.

If an engineering plant is to be operated as economically and efficiently as possible, none of the various safety factors can be overlooked.

## QUIZ

1. What are the primary purposes of peacetime operation of naval ships?
2. What is the primary cause of engineering troubles, such as improper operation of piping systems and malfunctioning of machinery?
3. When will an MMC in charge of the control engineroom assume the duties of the engineering officer of the watch?
4. During peacetime conditions, what is the objective of engineering training in the fleet?

5. The numerical comparison of the amount of fuel oil used to the amount of fuel allowed for a certain speed, or steaming condition, is referred to as what ratio?
6. When do most engineering casualties occur aboard ship during peacetime conditions?
7. What 3 major factors should be considered in the economical operation of main turbines?
8. How should the transfer of heat be minimized in a power plant?
9. What are 3 factors which contribute largely to habitable conditions in the engineroom as well as to good economy?
10. What is an over-all indication of an excessive feed water consumption rate?
11. At sea, the tubes in steaming boilers should be blown how frequently?
12. On small ships, what form is generally used as steaming orders?
13. When should the MM1 or C in charge of the engineroom watch inform the main engine control that his engineroom is manned and ready to light off?
14 The efficient and safe operation of the engineering plant aboard ship depends to a great extent on the close cooperation between which personnel?
15. What type of boiler is installed in destroyers, cruisers, battleships, and most carriers?
16. What is the operating pressure range of the no control superheat boiler (not separately fired)?
17. How much time is required to raise steam to full pressure in the boilers?
18. Under what conditions may a burner be lighted under the superheater side, prior to cutting it in on the main steam line?
19. In order to cut in the incoming boilers, without their superheaters in operation, the temperature of the steam in the lines must be lowered to how many degrees?
20. In securing boilers, when should tubes be blown?
21. On small ships, who generally supervises the preparation for coming into port and the operations that occur?
22. When will it be necessary to lower the maximum temperature of the superheated steam aboard a destroyer equipped with separately fired superheat control boilers?
23. Superheat may be raised or lowered at what maximum rate?
24. The difference between the superheater outlet temperature and the saturated steam temperature is known as what?

# CHAPTER 8

## ENGINEERING CASUALTY CONTROL

Engineering casualty control is concerned with the prevention, minimization, and correction of the effects of operational and battle casualties to the machinery, electrical, and piping installations. Its mission is the maintenance of all engineering services in a state of maximum reliability, under all conditions. The first objective under this mission is the effective maintenance of propulsion machinery, auxiliary and electric power, lighting, interior and exterior communications, fire control, electronic services, ship control, firemain supply, and miscellaneous services (heating, air conditioning, and compressed air). Failure to provide all normal services will affect the ship's ability to function effectively as a fighting unit, either directly (by reducing its power) or indirectly (by reducing habitability and thereby lowering personnel morale and efficiency). The second objective—which will contribute to the successful accomplishment of the first—is the minimization of personnel casualties and of secondary damage to vital machinery.

For detailed information you should familiarize yourself with the Engineering Casualty Control Book, the Damage Control Book, the Ship's Organization Book, and the Damage Control Bills. These publications may vary on different ships but in all cases they give the organization and the procedures to be followed in case of engineering casualties, damage to the ship, and other emergency conditions.

## FACTORS INFLUENCING CASUALTY CONTROL

The basic factors influencing the effectiveness of engineering casualty control are much broader than the immediate actions taken at the time of the casualty. Engineering casualty control reaches its peak efficiency by a combination of sound design, careful inspection, thorough plant maintenance (including preventive maintenance), and by effective personnel organization and training. CASUALTY PREVENTION IS THE MOST EFFECTIVE FORM OF CASUALTY CONTROL.

### Familiarity of Personnel With Plant Operation

Thorough instruction in the proper and normal operating procedures is the foundation upon which instruction in casualty procedures should be based. Complete familiarity with normal operation should be gained by all personnel involved before any attempt is made to carry out simulated casualties. From the design viewpoint, full information upon which to base improved designs should be contributed by the operating forces.

### Influence of Design

Sound design influences the effectiveness of casualty control in two ways: (1) elimination of weaknesses which may lead to material failure, and (2) installation of alternate or standby means for supplying vital services in the event of a casualty to the primary means.

Both of these factors are employed in the design of naval vessels. The second factor is carried out, in the case of individual units, by the installation of duplicate vital auxiliaries; by the use of loop systems and cross connections; and by the installation of complete propulsion plants designed to operate as isolated units (split-plant design).

### Preventive Maintenance

Preventive inspection and maintenance are vital to successful casualty control, since these activities minimize the occurrence of casualties by material failures. Continuous

detailed inspection procedures are necessary not only to discover partly damaged parts which may fail at a critical time, but also to eliminate the underlying conditions which lead to early failure (maladjustment, improper lubrication, corrosion, erosion, and other enemies of machinery reliability). Particular and continuous attention must be paid to the following external evidences of internal malfunctioning:

1. Unusual noises.
2. Vibrations.
3. Abnormal temperatures.
4. Abnormal pressures.
5. Abnormal operating speeds.

Operating personnel should thoroughly familiarize themselves with the temperatures, pressures, and operating speeds of equipment specified for each operating condition, in order that departures from normal operation will be more readily apparent. It must not be assumed that an abnormal reading on a gage, or other instrument recording operating conditions of machinery, is caused by an error in the gage. Each case should be investigated to establish fully the cause of the abnormal reading. The installation of a spare instrument, or a calibration test, will quickly determine if an instrument error exists. All other cases must be traced to their source, if preventive maintenance is to be effective. Some specific examples of advanced warning of ultimate failure are outlined in the following paragraphs.

Because of the safety factor commonly incorporated in pumps and similar equipment, considerable loss of capacity can occur before any external evidence is readily apparent. Changes in the operating speeds from normal for the existing load in the case of pressure-governor-controlled equipment should be viewed with suspicion. Variations from normal in chest pressures, lubricating oil temperatures, and system pressures are indicative of either inefficient operating procedures or poor condition of machinery.

In cases where a material failure occurs in any unit, a prompt inspection should be made of all similar units to

determine if there is incipient danger of the same failure. Prompt inspection may eliminate a wave of repeated casualties.

Abnormal wear, fatigue, erosion, or corrosion of a particular part may be indicative of a failure to operate the equipment within its designed limits of loading, velocity, and lubrication, or it may indicate a design or material deficiency. In any of the above cases, special inspections to detect repeated damage should be undertaken as a routine matter, unless corrective action can be taken which will ensure that such failures will not occur.

Strict attention must be paid to the proper lubrication of all equipment, including frequent inspection and sampling to determine that the correct quantity of the proper lubricant is in the unit. It is good practice to make a daily check of samples of lubricating oil in all auxiliaries. Such samples should be allowed to stand long enough for any water to settle. Where auxiliaries have been idle for several hours, particularly overnight, a sufficient sample to remove all settled water should be drained from the lowest part of the oil sump. Replenishment with fresh oil to the normal level should be included in this routine. An unusual quantity of fresh water in the oil is normally indicative of either poorly fitted or worn carbon packing on turbine-driven pumps handling fresh water.

Salt water may enter the oil from the salt-water pump glands, from the salt-water-cooled oil coolers, or from salt water dripping or spraying on the unit. The presence of salt water in the oil can be detected by drawing off the settled water by means of a pipette and by running a standard chloride test. A sample of sufficient size for test purposes can be obtained by adding distilled water to the oil sample, shaking vigorously, and then allowing the water to settle before draining off the test sample. Because of its corrosive effects, salt water in the lubricating oil is far more dangerous to a unit than is an equal quantity of fresh water. Salt water is particularly harmful in the case of units containing oil-lubricated ball bearings. Where such units are found to be

subject to salt-water contamination of the lubricating oil, it is essential to drain the oil as soon as possible, flush thoroughly, and refill with fresh oil.

## CASUALTY CONTROL TRAINING

Casualty control training must be a continuous step-by-step procedure with constant refresher drills. Realistic simulation of casualties must be preceded by adequate preparation. The amount of advance preparation required is not always readily apparent unless care is exercised to visualize fully the consequences of any error which may be made in handling simulated casualties originally intended to be of a relatively minor nature. The simulation of major casualties and of battle damage must be preceded by a complete analysis and by careful instruction to all participants. A new crew must be given an opportunity to become familiar with the ship's piping systems and equipment, prior to simulating any casualty which may have other than purely local effects.

In the preliminary phases of training, a "dry run" is a useful device for imparting a knowledge of casualty control procedures, without endangering the ship's equipment by too realistic a simulation of a casualty before sufficient experience has been gained. Under this procedure, a casualty is announced, and all individuals are required to report as though action were taken (an indication must be made that the action was simulated). Definite corrective action motions can be made, and with careful supervision the timing of individual actions can appear to be very realistic. Regardless of the state of training, such dry runs should always be carried out before any actual attempt is made to simulate realistically any involved casualty. Similar rehearsals should precede relatively simple casualties whenever an appreciable proportion of men, new to the ship, are involved, and particularly after an interruption of regularly conducted casualty training (such as is occasioned by periods of naval shipyard overhauls).

## PROMPT CORRECTION OF CASUALTIES AND OPERATION OF DAMAGED EQUIPMENT

The speed with which corrective action is applied to an engineering casualty is frequently of paramount importance. This is particularly true when dealing with casualties which affect the propulsion power, steering, and electrical power generation and distribution. If casualties associated with these functions are allowed to become cumulative, they may lead to serious damage to the engineering installation—damage which often cannot be repaired without loss of the ship's operating availability. Where possible risk of permanent damage exists, the CO has the responsibility of deciding whether to continue operation of equipment under casualty conditions; and such action can be justified only where the risk of even greater damage, or loss of the ship, may be incurred by immediately securing the affected unit. For example, an entire plant with abnormal salinity present could be operated to enable the ship to steam clear of an area of possible enemy attack. However, all possible steps must be taken to shorten the period of hazardous operation.

It is reemphasized that whenever there is no probability of greater risk, the proper procedure is to secure the malfunctioning unit as quickly as possible even though considerable disturbance to the ship's operations may occur. Although speed in controlling a casualty is essential, action should never be undertaken without accurate information; otherwise the casualty may be mishandled, and irreparable damage and possible loss of the ship may result. War experience has shown that the cross-connecting of intact plants with a partly damaged one must be delayed until it is certain that such action will not jeopardize the intact plant. Speed in the handling of casualties can be achieved only by a thorough knowledge of the equipment and associated systems, and by thorough and repeated training in the routine required to handle specific predictable casualties.

## PHASE NATURE OF CASUALTY CONTROL

The handling of any casualty can usually be divided into three phases: limitation of the effects of the damage, emergency restoration, and complete repair.

The first phase is concerned with immediately controlling the casualty so as to prevent further damage to the unit concerned and to prevent the casualty from spreading through secondary effects.

The second phase consists of restoration, in so far as practicable, of the services which were interrupted as a result of the casualty. In many cases, the completion of this phase eliminates all operational handicaps, except for the temporary loss of standby units—i. e., ability to withstand further failure. If no damage to, or failure of, machinery has occurred, this phase usually completes the operation.

The third phase of casualty control consists of making repairs which will completely restore the installation to its original condition.

## SPLIT-PLANT OPERATION

The fundamental of engineering damage control is SPLIT-PLANT OPERATION. It follows the wisdom of the old proverb of "not putting all your eggs in one basket," and its purpose is to minimize the damage that can be done by any one hit.

Most naval vessels built primarily as warships have at least two engineering plants. The larger combatant ships have four individual engineering plants.

Split-plant operation means dividing your boilers, engines, pumps, and other machinery so that you have two or more engineering plants, each complete in itself, and each operating its own fuel oil pumps and source of supply. Each turbine installation is equipped with its own condenser, air ejector, lubricating oil pump, and other auxiliaries. Each engineering plant operates its own propeller shaft. Then, if one pair of boilers, or one turbine, is put out of action by explosion, by shellfire, or by flooding, the other plant could

probably continue to drive the ship ahead, though at somewhat reduced speed.

Split-plant operation applies to all piping and electrical systems aboard ship. Split-plant operation is not a good luck charm against damage that would completely immobilize the entire engineering plant; but it does reduce the chances of such a casualty, and prevents an injury to one plant from being transmitted to another, or from seriously affecting its operation. Thus, if you were not operating split-plant and a shell ruptured the main steam line to the forward turbine, you would lose steam from all the boilers. If you were operating split-plant, you would lose steam from only one set of boilers.

### Know Your Split Plant In the Event of Casualty

Split-plant operation is only the first of the important steps to be taken in the prevention of major engineering casualties. Other steps must be taken immediately when a casualty occurs. Failure on your part to understand the full meaning of split-plant operation may be the cause of unnecessary casualties.

The following example shows how lack of understanding caused heavy damage to a ship's main engine. The ship was operating with the plant split, when one boiler lost feed water. The Boilerman on watch, in the process of handling the low-water casualty, secured the bulkhead steam stops of both boilers. By so doing, he cut off all steam to one engine-room, including the steam supply to the auxiliary machinery. The lubricating oil pump stopped, with the engine still turning over from the drag; as a result, the main engine bearings wiped, and the turbine blading was ruined.

In analyzing engineering casualties where more than one unit of machinery, equipment, or system is involved, it has been found that the damage resulting from the casualties was caused by several mistakes. In general, this means that any one corrective step taken out of a possible 2 or 3 steps would have prevented the final damage. In the previous engineer-

ing casualty just discussed, the following actions should have been taken:

1. The Boilerman should have closed only the stop valves to the boiler that had the low water casualty. THIS ACTION WOULD HAVE PREVENTED THE TURBINE CASUALTY.

2. The Machinist's Mate should have cross-connected the auxiliary steam line, and the other systems, to the other plant. THIS ACTION WOULD HAVE PREVENTED THE TURBINE CASUALTY.

3. The shaft-driven lube oil pump should have been tested and maintained in a satisfactory operating condition. (If no such pump was installed, a shaft-driven lube oil pump should have been installed.) THIS ACTION WOULD HAVE PREVENTED THE TURBINE CASUALTY.

This one casualty is given as an example; several other types of engineering casualties, resulting from two or three mistakes made simultaneously, have occurred aboard ships.

Split-plant operation should be maintained as long as it is advantageous for the ship's safety and operation. In certain cases, it may be better to cross-connect in order to give the ship maximum speed or maneuverability to overcome or minimize a casualty.

### Fuel Oil System

The fuel oil system is generally arranged so that suction can be taken from any fuel oil tank and the oil pumped to any other fuel oil tank; this is accomplished by means of the fuel oil booster and transfer pumps. Fuel oil service pumps are used to supply oil from the service tanks to the boilers. In split-plant operations the forward fuel oil service pumps of your ship are lined up with the forward service tanks, and the after service pumps are lined up with the after service tanks. The cross-connection valves in the fuel oil transfer line must be closed except when oil is being transferred.

The main reason for securing the fuel oil cross-connecting lines is to prevent major casualties. For example, if all the boilers received fuel oil from the same service tanks and the tanks were ruptured by a torpedo or by a near miss bomb, the results would be disastrous. The entire fuel oil system would

become contaminated with salt water, the fires under the boilers would go out, and your ship would stop dead in the water.

Some ships are provided with sluicing valves that make it possible to sluice oil (or water) from one side of the ship to the other. These sluicing valves must be kept closed at all times except when fueling the ship, transferring fuel oil, and taking on fresh water. Therefore, if the ship is damaged, the liquid cannot sluice across to the low side. This helps to control stability at a time when it is most needed. All fuel oil tank manifold valves are closed except when they are in actual use. This precaution will prevent fuel oil (or sea water) from flowing from tanks on one side of the ship to the other side—an essential precaution when a damaged ship has a heavy list on it.

Many fuel oil service tanks are provided with both upper and lower suction connections. Inasmuch as water is heavier than oil it tends to settle to the bottom of the tanks; and, as a certain amount of water is not uncommon in oil, it is safer to use the upper suction when steaming under battle conditions. Precautionary steps should be taken by the Boilermen to see that standby fuel oil tanks and pumps are ready for immediate use.

### Feed Water System

During split-plant operation, the main feed system (including the main condensate system) may be divided into two or more separate and complete systems. In other words, each engineering plant would be provided with an individual main feed system. In splitting the plant, keep the pressure from as much of the feed system as possible. This reduces the area subject to casualties. The emergency feed pumps should be kept warmed up and in a standby condition, ready to supply feed water to the boilers if the main feed and booster pumps suffer casualty, or if there is a delay in cross-connecting the main feed system. Emergency feed pumps are so connected that they can take either a "hot suction" from the booster pumps or a "cold suction" from the reserve feed tanks.

### Main Steam System

The main steam system varies somewhat on the different types of ships. Smaller types of ships may have the forward and the after system CROSS-CONNECTED to form a complete system throughout the enginerooms and firerooms, whereas larger types of ships have independent forward and after systems. The method of supplying steam to the propulsion turbines, however, remains essentially the same. On small combatant ships the main steam system is split fore and aft to form two separate systems. On large combatant ships there are no main steam connections between the two forward and the two after plants, and the main steam is split athwartships; this gives a total of four separate main steam systems. Valves are also provided at strategic points, such as at bulkheads and at the boilers, to permit effective isolation in case of damage.

The principle of split-plant operation applies to Diesel-electric plants as well as to steam plants. Unfortunately, it does not apply to many auxiliary vessels, because most of them have but one engineroom.

## ENGINEROOM CASUALTIES

For each class of ship, the type commander formulates engineering casualty procedures which are applicable to the specific type of engineering plant. However, BuShips recommends general procedures for the control of typical engineroom casualties.

### Propulsion and Auxiliary Machinery

In the event of a casualty to a component part of the propulsion plant, the principal doctrine to be impressed upon operating personnel is the prevention of additional or major casualties. Under normal operating conditions, the safety of personnel and machinery should be given first consideration. Where practicable, the propulsion plant should be kept in operation by means of standby pumps, auxiliary machinery,

and piping systems. The important thing is to prevent minor casualties from becoming major casualties, even if it means suspending the operation of the propulsion plant. It is better to stop the main engines for a few minutes than to put them completely out of commission, so that major repairs are required to place them back into operation. In case a casualty occurs, the officer or CPO in charge of the watch should be notified as soon as possible; he in turn must notify the OOD if there will be any effect on the ship's speed or on the ability to answer bells.

JAMMED THROTTLE. If the ahead throttle valve jams open, close the guarding valve or the main line stop valve. To remedy the situation in an extreme emergency, the astern throttle may be used.

If the astern throttle valve jams open, close the line stop valves. To remedy the situation in an extreme emergency, open the ahead throttle. If necessary, the ship can be operated by means of the guarding valve.

LOSS OF STEAM PRESSURE IN THE ENGINEROOM. In the event of a loss of steam pressure, the following action should be taken:

1. Close the main throttle and trip the turbogenerator to prevent the main steam pressure from dropping below the designated minimum operating pressure, normally about 75 percent of the rated pressure. If the electrical load is split, the bus tie between the two main switchboards must be closed immediately, pending supply of steam to the turbogenerator from the other plant.
2. Open the main and the turbogenerator steam cross connections.
3. Open both auxiliary steam cross-connection valves.
4. Secure the boiler stop valves.
5. Shift to electrical auxiliaries as desired.

LOCKING AND UNLOCKING OF SHAFT UNDER WAY. In locking the shaft, the following action should be taken:

1. Stop the main shaft by means of the astern turbine.
2. Slow ship's speed to one-half full power speed or less, if necessary, or to the designated locking speed.

3. Engage the turning gear at locking shaft speed, and immediately apply the brake.

4. Note the astern steam pressure and the ship's rpm on the other shaft(s), when the shaft is held stationary for locking.

5. Close the astern throttle slowly.

In unlocking the shaft, the following action should be taken:

1. Reduce the temperature of the main steam as much as practicable.

2. Bring the ship to the same speed (rpm) at which the shaft was locked.

3. Open the astern throttle until the same astern steam pressure, used when the shaft was locked, is obtained.

4. Disengage the turning gear immediately. (It may be necessary to adjust the astern throttle pressure slightly in order to disengage the turning gear. The turning gear brake may then be released.)

5. Slowly close the astern throttle.

6. Open the ahead throttle slowly and continue under way.

CAUTION. If the shaft has been locked for more than 5 minutes, the turbine rotor may become bowed. In this case follow the procedure outlined in chapter 3, "Main Reduction Gears," of this training course.

VIBRATION. If the TURBINE BEGINS TO VIBRATE, the following action should be taken:

1. Slow the turbine and reduce the superheat temperature. A rumbling noise probably indicates the presence of water in the casing, either from boiler priming or from inadequate casing drainage.

2. If the turbine has been standing more than 5 minutes without being spun, it is probable that the rotor has bowed temporarily. Usually a brief slowing of the turbine will permit the rotor shaft to straighten.

If the SHAFT VIBRATES EXCESSIVELY, the following action should be taken:

1. Slow the engine. Speed up the other engine to maintain speed.

2. If vibration continues, slow all engines until the cause of the trouble can be determined.

3. Inspect the main shaft bearings and the bulkhead stuffing glands.

4. If feasible, investigate the propeller, the fairwaters, and the rope guards.

5. If vibration continues and is excessive at required speeds, stop the shaft and lock it.

NOISES. In the event of a METALLIC NOISE in the turbine, the following action should be taken:

1. Stop the turbine.

2. Lock the shaft and do not operate until the cause of the noise has been determined and remedied.

In the event of an UNUSUAL NOISE IN THE REDUCTION GEAR and if tooth failure is not probable, the following action should be taken:

1. Slow the engine immediately, and stop it if the noise persists.

2. Check the oil discharge pressure, the temperature of the bearings, and the operation of oil sprays; check the strainers for the presence of babbitt or foreign matter.

If a LOUD OR ROARING NOISE is heard, proceed to (1) stop the engine and check the shaft immediately, and (2) lock the shaft and as far as the ship's operations permit, make a preliminary investigation.

HOT BEARINGS. If the turbine bearings are hot, the following action should be taken:

1. Check to see that there is a proper amount of oil discharge from the cooler, and an adequate supply to the bearings.

2. Slow the engine, if necessary, to maintain a bearing temperature within the limit defined by the manufacturer, or as experience dictates.

3. Place burlap or rags over the top of the bearing housing, and run a slow stream of salt water over the housing.

Care should be taken that the water is not splashed into the oil or into the gland sealing systems.

In the case of reduction gear bearings, do not operate gears, except in an emergency, until the bearings have been examined. Wiped bearings would permit pinion or shaft misalignment, and thereby result in uneven wear of the gears.

If the TURBINE OR SHAFT BEARING BECOMES OVERHEATED, the following treatment is recommended:

1. Once the bearing temperature has been reduced from the critical range by methods listed under turbine bearings, above, proceed at a speed that will keep the bearing temperature satisfactory.

2. If the bearing has not dropped sufficiently to damage the turbine shaft packings, thus allowing the shaft to whip or transfer an excessive load to adjacent shaft bearings, proceed at moderate speeds for the minimum period necessary to permit renewal of the bearing.

3. If the bearing damage is believed to be greater than assumed above, turn over the shaft at a minimum speed to prevent the bearing from freezing. Then stop and lock the shaft. Continue operation of the forced lubrication system.

4. Operate the lubricating oil purifier continuously to remove any flakes of babbitt, or other foreign matter, which might become entrained in the oil system.

CRUISING TURBINE OUT OF COMMISSION. If the cruising turbine doesn't operate properly, the following action should be taken:

1. Disconnect the cruising turbine.
2. Insert the locking device.
3. Secure the valves, gland seal, gland leak-off, and drains of the cruising turbine.

LOSS OF VACUUM. The major causes for a loss of vacuum are as follows:

1. EXCESSIVE AIR LEAKAGE INTO THE VACUUM SYSTEM:
   a. Insufficient gland sealing steam
   b. Vent valve on idle condensate pump open
   c. Loop-seal filling valve open
   d. Bypass valve on drain tank open

e. Drain tank float valve stuck open
f. Taking make-up feed from empty feed bottom
g. Leakage of flanges, fittings, or valve stem packings under vacuum.

2. IMPROPER FUNCTIONING OF THE AIR-REMOVAL EQUIPMENT:

a. Insufficient steam to the air ejectors
b. Foreign matter lodged in the air ejector nozzle(s)
c. Erosion of the air ejector nozzle, as a result of lowered vacuum over a period of time.

3. IMPROPER DRAINAGE OF CONDENSATE FROM THE CONDENSER:

a. Low speed of condensate pump, indicating malfunctioning of the pump's speed-limiting governor
b. Condensate pump air-bound because of the vent connection from the first stage being closed or not opened wide.

4. INSUFFICIENT FLOW OF CIRCULATING WATER:

a. Improper adjustment of the overboard discharge valve (the main injection valve being wide open whenever the condenser is under vacuum)
b. Inadequate speed of the main circulating pump
c. Plugged tubes, resulting from mud, shells, small fish, or kelp being trapped against the injection strainer bars or in the inlet water chest
d. Air trapped in condenser.

5. HIGH INJECTION TEMPERATURE:

Basically, the injection temperature limits the maximum vacuum (minimum absolute pressure) obtainable in a specific plant, assuming the condenser, associated equipment, and piping under vacuum to be clean and properly operated.

LEAK IN CONDENSER. If there is a minor leak in the condenser and the ship's prospective arrival time is less than 24 hours, continue operating the affected shaft. Isolate the condensate system, limit the number of boilers on the engine involved, and blow down the boiler(s) as necessary to keep the boiler salinity within the specified limit.

However, if the leak is serious, the following action should be taken:

1. Stop the engine.
2. Shift drains, auxiliary exhaust, and turbogenerator exhaust to the auxiliary condenser.
3. Retain the main lubrication oil system in operation, and proceed on the other engine.
4. Test the condenser and plug the leaking tube(s).

STOPPAGE OF COOLING WATER TO AUXILIARIES. If the cooling water to the auxiliaries fails, the following action should be taken:

1. Take cooling water from the firemain, and start pump(s) as necessary.
2. Cross-connect the independent cooling water system, if provided.
3. Use a handy billy and hose, if other means fail.

## Feed Water System

In this chapter, discussion of feed water system casualties is limited to the deaerating feed tank and to the empty feed bottom in use for make-up feed.

CASUALTY TO DEAERATING FEED TANK (DFT). In the event of a casualty to the deaerating feed tank and if steaming split-plant with all deaerating feed tanks in use, the following action should be taken:

1. Open the crossover valves in the condensate system, the main feed system, the auxiliary exhaust steam line, the high-pressure drains, and the fuel oil heater drains to the associated plant.
2. Secure the main feed and the booster pumps.
3. Secure the exhaust steam to the DFT.
4. Secure the high-pressure drains to the DFT.
5. Secure the fuel oil heater drains to the DFT.
6. Secure the condensate discharge valve to the DFT.
7. Secure the recirculating system and all the vent valves on the DFT.

If steaming with a cross-connected plant with one deaerating feed tank in use, the following action should be taken:

1. Start the standby main feed and the booster pumps in the opposite engineroom.

2. Secure the main feed and the booster pumps in the engineroom having the casualty to the DFT.

3. Secure the exhaust steam to the DFT and route it to the opposite DFT.

4. Secure the high-pressure drains, and route them to the opposite DFT.

5. Secure the fuel oil heater drains, and route them to the opposite DFT.

6. Secure all the vent and the recirculating valves on the DFT.

7. Secure the condensate discharge to the DFT, and discharge it into the opposite DFT.

8. Open the vent on the DFT in use for feed, and shift make-up feed to that engineroom.

DEAERATING FEED TANK WATER LEVEL DROPS DURING STEADY STEAMING. If a decrease in the deaerating feed tank water level is noted during steady steaming, proceed as follows:

1. Check the condensate pump for operation.

2. Check to see that the manually operated recirculating valves are closed. (On a ship equipped with a bypass regulating valve around the air ejector unit, check the automatic valve for proper operation.)

3. Check the water level in the main condenser. Start the standby condensate pump, if the water level is too high.

4. Check the other engineroom for make-up or excess feed water conditions.

5. Take on the make-up feed gradually.

EMPTY FEED BOTTOM IN USE FOR MAKE-UP FEED. The following action should be taken with an empty feed bottom in use for make-up feed:

1. Shift to another reserve feed tank for make-up feed.

2. Refill the empty feed tank by any of the following methods:

   a. Distill to the empty feed tank.

   b. Line up the emergency feed pump to take a cold

suction from the opposite tank, and discharge to the empty tank.

c. Start the emergency feed pump in the other fireroom, taking suction from the reserve feed tank which is lined up for cold suction, and discharge to the empty reserve feed tank in the other fireroom.

d. Open the condensate discharge cross connection and make-up feed in the other engineroom.

e. Open the excess-feed line to the empty reserve feed tank, or open the drain from the DFT to the empty reserve feed tank.

f. Open the feed booster cross connection, and take make-up feed in the other engineroom.

g. Open the excess-feed line to empty the reserve feed tank, or open the drain from the DFT to the empty reserve feed tank.

h. Line up the emergency feed pump to discharge to the condensate discharge cross-connection system.

### Lubricating System

It must be impressed on all operating personnel concerned with the ship's lubrication system that even a momentary loss of flow of lubricating oil will result in localized overheating and probable slight wiping of one or more bearings. Such wiping may result in only a momentary rise in the temperature of the lubricating oil discharge from the bearing(s). Damage can be prevented or minimized by stopping the shaft rotation and quickly restoring the lubricating oil flow. Continued operation with wiped bearings will cause serious derangement to the shaft packings, oil seals, and blading.

Loss of or Low Lube Oil Pressure. Operating personnel must thoroughly understand the precautions and the procedures to prevent low lubricating oil pressure.

Loss of lubricating oil pressure may be caused by:

1. Failure of the system itself, including the main lubricating oil pumps.

2. Failure of steam or electrical power supply to the main

lubricating oil pumps; or damage to boilers, to steam lines, or to electrical equipment.

Failure to component parts of the lube oil system may be caused by the presence of dirt, rags, or other foreign matter resulting from improper cleaning. Failure of the system may be caused by a piping failure, by a failure of the operating pump, or by failure of the standby pump to start. Standy pumps should be maintained ready to start the moment the pressure drops below the prescribed operating range. If automatic starting devices are not available on steam-driven pumps, the pumps must be lined up so that opening the throttle is the only action required to start the pumps. Steam supply lines to standby pumps should be drained continuously. Where electrical pumps are installed, personnel must be thoroughly familiar with alternate sources of power.

Loss of steam pressure resulting from battle damage may be unavoidable. Split-plant operation is prescribed when maximum damage control is required to prevent total loss of power; therefore, cross-connection valves between split plants must not be opened until the damage is isolated.

Complete loss of steam pressure resulting from operational casualties, such as low water in boilers or water in the fuel oil, usually can be prevented by the throttleman closing the throttle as soon as possible and by securing the auxiliary machinery that is not required. In this way there will be a conservation of available steam for the lubricating oil pumps and for the vital auxiliary machinery. In addition, time will be provided to open the cross-connection valves.

The general procedure for low lubricating oil pressure is as follows:

1. Upon failure of the oil pressure, immediately stop the affected shaft and simultaneously endeavor to regain lubricating oil pressure.

2. If steam pressure is available, stop the shaft by using the astern throttle. Engage the jacking gear and apply the brake. If the speed is in excess of one-half full power speed, stop the shaft by means of the astern turbine,

slow down the ship to a safe speed, and then lock the shaft. Listen for, and endeavor to locate, the source of any unusual or abnormal sounds. After the affected shaft is secured, the ship's speed may be increased to the limit for locked shaft operation.

3. If steam pressure is lost in one engineroom during split-plant operation, and unless the tactical situation positively prevents, take way off the ship by backing the other engine(s). Concurrently determine the nature of the casualty causing the loss of steam.

   a. If a loss of steam pressure in an engineroom will not cause a loss of steam to the other plant, open the auxiliary and the main steam cross-connections immediately.
   b. If damage causes a loss of steam to the other plant, isolate the damage and then open the auxiliary and the main steam cross connections as soon as possible.
   c. Stop and lock the affected shaft as soon as steam is available.

4. Concurrently, make every effort to regain the lubricating oil pressure:

   a. Check the lubricating oil pump in use.
   b. Start the standby pump (if it is not in operation).
   c. Shift the duplex strainers.
   d. Check the sump level. If low, replenish oil.
   e. Locate and repair any leaks.

5. Concurrently with the above steps, inspect all bearings and endeavor to determine which have been overheated. Do not rely on thermometers alone (a thermometer may have indicated only a slight, momentary rise).

6. Secure gland sealing steam and the main air ejectors to minimize main turbine rotor distortion.

7. Inspect and clean the lubricating oil strainer basket not in use. Note whether flakes of bearing metal are present in the strainer.

8. Start the lubricating oil purifier, if it is not already in use.

9. Continue circulation of the lubricating oil until the bearings are sufficiently cool for inspection. Circulate oil at all times, except when inspecting bearings, so that lubrication will be provided if the shaft-locking gear should fail.

10. Take bearing-wear micrometer readings of all bearings and of axial clearances where means are provided.

11. Proceed with the inspection of the bearings. Raise bearing caps and roll out shells. The inspection must be as thorough as circumstances will permit, weighing the importance of subsequent reliable performance against the time required to inspect suspected bearings.

12. It is possible that the bearing trouble is isolated and only one or a few bearings are wiped. It is realized that, immediately following a machinery derangement, a thorough examination of the main reduction gear bearings may be impracticable; however, the following information should be considered when such a casualty is being investigated:

a. The oil strainer basket in use should be examined for the presence of babbitt flakes.

b. All turbine and cruising reduction gear bearings should be thoroughly inspected. (In the event of loss of oil pressure, the cruising reduction gear bearings are the first to be damaged.)

c. The main reduction gear bearings can be divided into 3 groups, in accordance with the rotational speed of the journals and the probability of the bearings becoming wiped. The rotational speed of the two high-speed pinions is the same as that of the respective turbine rotors. The speed of the bull gear shaft is the same as that of the propeller shaft. The speed of the 4 intermediate speed gear and pinion assemblies is, approximately, one-half the speed of the low-pressure turbine rotor.

d. The high-speed pinion and the intermediate-speed pinion bearings of the main reduction gear should be examined, through the inspection openings, for possible flow of babbitt from the bearings.

e. Reduction gear bearing thermometers should be loosened to check for oil flow from the wells. Absence of oil flow from the well, with the thermometer removed, indicates that the bearing may be wiped to the extent that the oil passage to the thermometer has been closed. When such a condition exists, a below-normal reading would be shown by the thermometer when the shaft is operating. Also there may be a stoppage of oil to the bearing.

f. If the turbine bearings are found to be in good condition, it can be assumed that the main reduction gear bearings are also in good condition.

g. If a partial examination of the main reduction gear bearings shows no indication of wiping and only the cruising turbine bearings are found to be wiped, the main reduction gear bearings may be assumed to be undamaged. The shaft may be operated at the minimum speed which the tactical situation will permit until such time as a thorough examination of the main reduction gear bearings can be made by a repair activity.

h. If several of the bearings for the high-pressure turbine, and (especially) the low-pressure turbine, are found to be wiped, it is likely that the high-speed pinion bearings for the main reduction gear are also wiped. The shaft should not be operated until the high-speed pinion bearings have been thoroughly examined. If these bearings are wiped, then the intermediate-speed gear and pinion bearing should be inspected. Whenever possible, these inspections and repairs should be made at a naval shipyard.

The above information applies when the lubricating oil pressure of the entire system is lost. However, if it is noted that a bearing is overheated because of local loss of oil or presence of foreign matter, and it becomes necessary to shut down the turbine, it should be slowed down, and kept turning over at a slow speed, until the bearing and journal have cooled sufficiently. If the shaft motion is stopped quickly,

the bearing metal may freeze to the shaft and make repairs much more difficult.

Cooler Tube Carries Away. The action to be taken is as follows:

1. If it is permissible to reduce speed, bypass the cooler; operate at speeds below the critical bearing temperature; and strike down oil from the storage tank to the sump in order to restore the working level.

2. If it is not permissible to reduce speed sufficiently, or if the oil leak is not serious and there is an adequate supply of oil on board, increase the lubricating oil pressure so that oil will leak into the waterside of the cooler rather than vice versa; and pump make-up oil into the sump tank.

Lube Oil Leak Into Engineroom. The action to be taken is as follows:

1. If it is not permissible to secure the engine, plug or patch the leak so as to stop oil loss and prevent a fire hazard from being created.

2. Inspect the sump oil level, and strike down make-up oil as necessary.

High Oil Level in Reduction Gear Sump. The action to be taken is as follows:

1. Obtain permission from the OOD to slow the engine.
2. Pump down the sump tank to the proper level.
3. Determine the cause and correct the trouble.

Excessive Oil Pump Discharge Pressure. The action to be taken is as follows:

1. Inspect the constant pressure pump governor for proper operation.

2. Inspect the strainer and all parts of the lubricating oil system for restrictions of oil flow. (See articles 45–86 and 45–87 of BuShips *Manual*.)

## FIREROOM CASUALTIES AND THE MM1 OR C

As an MM1 or C, you will be concerned with various fireroom casualties. In general, the Boilerman is responsible for taking the necessary steps to control fireroom casualties.

However, it will become necessary for the Machinist's Mate to take proper procedures to control the casualties which have a direct effect upon the operation of the engineroom. Close cooperation between the engineroom and the fireroom is necessary for the most efficient handling of engineering casualties.

In all cases, the Boilerman will notify the engineroom of the fireroom casualties. The necessary action that must be taken will be based on the report given by the Boilerman.

If the Boilerman notifies the engineroom that there is OIL IN THE FUEL OIL HEATER DRAINS, the Machinist's Mate should immediately check to see if oil has carried through to the inspection tank. If any oil has carried through, the inspection tank drain should be shifted to the bilges until the drains are clear of oil.

The Boilerman's first action would be to shift the drains to the bilges and shift to another fuel oil heater. When the drains are clear, he will shift the fuel oil heater drains back to the drain line. Any oil in the drain system will be carried through to the engineroom. When the fuel oil heater drain inspection tank has cleared up, the Machinist's Mate will shift his drains to the drain line.

If the Boilerman informs the engineroom that the SALINITY OF THE BOILERS IS EXCESSIVELY HIGH and that the boilers may be receiving feed water which has a high salinity content, the Machinist's Mate should immediately check such sources of salt contamination as may be his responsibility.

The most prolific source of contamination of water in the boilers is the leakage of salt water into the feed water system. Leakage may occur in the following parts of the system:

1. Condensers, main, auxiliary, and dynamo.
2. Salt-water-cooled air ejector condensers.
3. Distilling plants.
4. Salt-water-cooled gland exhaust condensers.
5. Leaky feed suction and drain lines which run through the bilges. At times, open funnel drains are an unsuspected source of salt-water entry.

If the Boilerman notifies the engineroom that it is necessary to blow down the boilers in order to reduce salinity, the Machinist's Mate should see that water is added to the deaerating feed tank. This water should be added slowly in order to maintain the exhaust pressure and the temperature of the deaerating feed tank. Then the Boilerman should cautiously take on water for the blow-down; an excess opening of the feed check valves may affect the discharge pressures of the main feed and booster pumps. The water level in the deaerating feed tank must be watched very closely. Before the water level of the tank gets too low, the fireroom should be notified to cease blowing down the boiler. The amount of reserve feed water that is available for blow-down purposes should be estimated. When this water has been used, the blow-downs should be discontinued. A sufficient supply of water must be held in reserve for the operation of the ship.

If it is impossible to maintain the salinity content of the boiler water within the specified range, it may be necessary to limit the firing rate in order to prevent carryover.

In the case of the fireroom casualty, HIGH WATER IN THE BOILER, the Machinist's Mate should close the main throttle, stop the shaft, and trip the turbogenerator. The source of auxiliary and turbogenerator steam must be shifted. The above procedures should be performed simultaneously. The Boilerman will close the feed check valve and secure the burners and the air supply. He will also close the main, the turbogenerator, and the auxiliary steam boiler stop valves. The closing of the feed check valve will probably call for immediate attention to the main feed and to the booster pumps. After the Boilerman has secured the boiler(s) he will blow the water down to the designed level, relight the boiler, and cut in.

Should high water occur on all the boilers furnishing steam to a particular plant while the ship is steaming split-plant, the situation will call for immediate cross-connecting.

If the shaft was locked to prevent rotation, see that no unusual noise exists when placing the plant back in service.

In turbogenerators, it is particularly true that priming results in slugs of water entering the turbine. This may cause failure of a thrust bearing.

THE FAILURE OF A FORCED DRAFT BLOWER may be serious, depending upon the existing conditions. If two blowers are in use and the speed of the ship is high, it will be necessary to slow down in the event that one blower fails. If only one blower is in use, its failure will necessitate the securing of the boiler until another blower can be started.

When there is LOSS OF FUEL OIL SUCTION to the steaming boilers, the steps to be taken to correct this casualty depend upon the existing conditions (whether steaming cross-connected or split-plant). If steaming split-plant, you should cross-connect immediately. The Boilerman will immediately secure all boilers of the affected plant. Having secured the boiler stops, he will need steam from another plant in order to operate the forced draft blower and the fuel oil service pump. After a satisfactory fuel oil suction has been picked up, the Boilerman will relight and cut in on the line. Then the plant can be split just as it was originally.

In steaming cross-connected on one fireroom, the above-mentioned casualty is more serious. The main throttles should be secured immediately. The Boilerman must see that at least one of the boilers is cut in on the auxiliary steam line. This is necessary in order to obtain steam for the forced draft blower, for the fuel oil service pump, and for the lube oil service pump; therefore, all available steam should be reserved for use in the fireroom. If the proper procedures are not immediately followed by the fireroom and engineroom personnel, the result will be that the ship will end up dead in the water, without any steam or power. Normal operating conditions can be resumed after a good fuel oil suction has been picked up and the boilers are up to full pressure.

When BRICK OR PLASTIC FALLS OUT OF THE BOILER FURNACE WALL, the boiler should be secured. If it is necessary to continue to operate the boiler until another can be brought in

on the line, burners adjacent to the defective brick or plastic area should be cut out, in order to avoid damage to the boiler casing. Since this procedure may result in a reduction in speed, the Boilerman will inform the engineroom of the estimated total steam output.

One of the fireroom casualties resulting in the loss of boiler power is LOW WATER IN THE BOILER; the water level drops out of sight in the 18-inch glass. When this casualty occurs, the boiler will have to be secured immediately, allowed to cool gradually, and then opened for investigation.

Another fireroom casualty which results in a loss of boiler power is the carrying away of a boiler tube or of other pressure parts of a boiler. In this case, it will be necessary to secure the boiler at once, and the boiler will be out of commission until repairs can be made.

Temporary securing of the boiler may be required when the following casualties occur:

1. Major fuel oil leaks in the fireroom
2. Fuel oil fire, either in the fireroom or in the boiler casing
3. Major flare-backs
4. Loss of feed pressure

For additional information regarding fireroom casualties, it is recommended that the MM1 and C refer to chapter 88, section 3, of BuShip's *Manual*, and to his ship's Engineering Casualty Control Book.

## BATTLE CASUALTIES

As an MM1 or C you will be responsible for handling battle casualties and you will have to know the location of isolating and cross-connecting valves and, also, which valves are remotely controlled. As a general rule, personnel safety is the first consideration in handling casualties and then material safety is considered.

Effective control of battle casualties depends on a good knowledge of the principal engineering piping systems and related equipment. Detailed information may be found in

the ship's Engineering Casualty Control Book, in the Damage Control Book, in the booklet of plans of the principal engineering systems, and in other applicable sources found aboard ship.

In the event of a battle casualty to an engineering piping system, the damaged section must be isolated and the system should be cross-connected, when possible. Emergency or alternate equipment should be used, when provided, to restore service to vital systems. Whenever practicable, emergency repairs should be made and the system restored to normal operation. Precautions should be taken to prevent additional damage which may result from any original casualty.

If a steam line in any space is ruptured, the space will be filled with steam to such an extent that it will have to be abandoned, and secured from the outside. After the space has been cooled, the damage can be isolated and as much of the plant operated as possible. Electrical power panels may have to be dried out before they can be used.

## SUMMARY

The importance of engineering casualty control cannot be overemphasized. A failure to immediately restore any of the ship's normal services reduces the vessel's damage resistance and impairs its ability to operate effectively. The effects of these engineering casualties are both direct and indirect. Directly, the casualties reduce the ship's mobility, and offensive and defensive power. Indirectly, the casualties reduce the ship's habitability, and thereby lower personnel morale and efficiency.

The primary duty of every man aboard ship should be to maintain the ship, the equipment, and the crew in action. In any situation demanding quick action aboard ship, you should know what to do, the causes of casualties, and how to handle the various engineroom casualties. Therefore, in order for you to be able to control engineroom casualties properly, it is important that your men master the normal

operation of the equipment at your battle station; otherwise you will be at a loss when an emergency occurs.

In controlling engineroom and fireroom casualties, you should follow the recommended procedures. The Engineering Casualty Control Book, BuShips *Manual*, and the manufacturer's instruction books for the equipment or systems that are at your stations, are the primary sources of instruction for handling engineroom casualties.

## QUIZ

1. Where can you find detailed information concerning the organization and the procedures to be followed for engineering casualties on board your ship?
2. What are the ways in which good design contributes to the effectiveness of casualty control?
3. List 5 general symptoms which indicate that a machine is not functioning properly.
4. When a material failure occurs in any unit, what should be done with all similar units?
5. Salt water in the lubricating oil is particularly dangerous to units containing what type of bearings?
6. Who has the responsibility for deciding whether to continue the operation of equipment under casualty conditions where possible risk of permanent damage exists?
7. What is the only possible justification for continuing to operate machinery under casualty conditions which involve possible risk of permanent damage?
8. Although speed in controlling a casualty is essential, what other factor is needed before taking action?
9. The handling of any casualty can usually be divided into what three phases?
10. When should sluicing valves be closed?
11. In case a casualty occurs aboard ship, who should be the first to be notified?
12. What should be done if the ahead throttle valve jams open?
13. What notations should be made by the throttleman when a shaft is locked?
14. When is it possible for a turbine rotor to become bowed?
15. If the turbine begins to vibrate, what does a rumbling noise generally indicate after the superheat temperature has been reduced?
16. How do wiped reduction gear bearings affect the gear wear?

17. If the cruising turbine is out of commission, what action should be taken?
18. If a decrease in the water level of the deaerating feed tank is noted during steady steaming, what checks should be made?
19. What is the result of a momentary loss of flow of lubricating oil?
20. In the event of a loss of oil pressure, what bearings are likely to be damaged first?
21. If a partial examination of the main reduction gear bearings indicates no wiping and the cruising turbine bearings are found to be wiped, what bearings may be assumed to be undamaged?
22. When are the high-speed pinion bearings for the main reduction gear likely to be wiped?
23. If there is a high oil level in the reduction gear sump, what action should be taken?
24. What action should immediately be taken by the Machinist's Mate when notified that there is oil in the fuel oil heater drains?
25. If the Boilerman indicates that he is going to give the boilers blow-downs in order to reduce the salinity, what action should be taken by the Machinist's Mate?
26. When there is water in the fuel oil suction, or loss of fuel oil suction to the steaming boilers, the steps to be taken to correct this casualty depend upon what conditions?
27. What may have to be done with a boiler when there are major fuel oil leaks in the fireroom?

# CHAPTER 9

## DAMAGE CONTROL ORGANIZATION AND SUPERVISION

The design of naval ships provides resistance to damage compatible with other military characteristics. The maintenance of the damage-resistance features of strength, watertight integrity, stability, proper displacement, proper distribution of liquids, and optimum material and personnel readiness before attack is as important for ultimate survival as are damage control measures after damage is sustained. In spite of all precautions and preparations that can be made before damage, however, the survival of the ship will often depend upon prompt and correct control measures after damage. It is necessary, therefore, to train the entire ship's company for any eventuality.

In order to ensure proper training and to provide prompt and correct control in event of casualties, a damage control organization must be set up and kept active. In some cases the Chief or First Class Machinist's Mate will be included in the damage control organization during drills and actual emergencies. In this organization, as in any other organization, the MM1 or C must understand the purpose and function of the organization in order to fully carry out his duties as a leading petty officer. He also may be called upon to instruct, supervise, and train nonrated men in basic damage control functions and procedures.

## SHIPBOARD ORGANIZATION

The basic meaning of organization is the combining of many small parts into a workable system. This system is the backbone of damage control. Your success as a leading petty officer in the organization will depend on your complete understanding and ability to help fit these small parts together, then to make them work. In order to do this, you should have a good fundamental knowledge of the damage control organization as it works in battle and in normal day-by-day routine.

The routine business and operation of the ship are controlled by the permanent ADMINISTRATIVE ORGANIZATION of the ship, an organization which consists of the various departments of the ship. In most cases a Machinist's Mate is assigned to one of the enginerooms of the Engineering Department.

In order to ready the ship for battle conditions or major emergencies, a BATTLE ORGANIZATION is set up. This organization includes the damage control organization. Since relatively minor periods of a ship's total time will be spent under battle conditions, this organization is more or less temporary. Do not let this word "temporary" mislead you, however, for the battle organization is a vital one and it must be kept up to the highest possible standards. Because of the relatively short periods of time that the ship's crew is exercised on stations under the battle organization, it is imperative that an all-out effort be made to perfect the functioning of the organization and the training of personnel. When all battle stations are "manned and ready" during battle conditions, a strict and efficient organization must be ready to function.

The damage control organization under battle conditions is also of a temporary nature, as it will include personnel that have only temporary or collateral duties in damage control. The membership of the group responsible to the damage control assistant under battle and normal conditions varies. For example, in battle condition, a repair station

on a ship will be made up of many different ratings. These men, as members of a repair party, will serve under the Damage Control Assistant. However, in normal ship's routine, only the DC, FP, and ME ratings will serve under him; the other members of the repair party will serve under their division heads in the different departments.

## OBJECTIVES OF DAMAGE CONTROL

The three basic objectives of shipboard damage control are: (1) To take all practical preliminary measures before damage occurs, such as maintenance of watertight integrity and fumetight integrity, maintaining reserve buoyancy and stability, removal of fire hazards, and upkeep and distribution of emergency equipment; (2) to minimize and localize damage, when it does occur, by such measures as control of flooding, preservation of stability and buoyancy, fire fighting, and first-aid treatment of personnel; and (3) to accomplish emergency repairs or restorations as quickly as possible after the occurrence of damage, by such measures as supplying casualty power, regaining a safe margin of stability and buoyancy, replacing essential structure, and manning essential equipment.

The ship's ability to inflict punishment upon or destroy the enemy or to perform any other assigned mission may well depend upon the effectiveness of damage control. Damage control then must be considered as an offensive, as well as a defensive, function.

Damage control is concerned not only with battle damage but also with nonbattle damage, such as fire, collision, grounding, or explosion. It may be necessary in port as well as at sea, and may involve the use of personnel and facilities of an undamaged ship.

## KNOWLEDGE NECESSARY FOR DAMAGE CONTROL

Damage control requires a detailed knowledge of ship construction, characteristics, compartmentation, stability, and of those appurtenances placed on board a ship to prevent or

control damage should a ship be endangered. Basically, the control of damage depends upon the ability of personnel to take prompt corrective action, using material which is available. Having a thorough knowledge of the ship will enable personnel to determine readily the corrective action to be taken.

In order to control any form of damage or casualty which may occur, it is essential to know the fundamentals of the various methods and procedures used to prevent damage to a ship, and to protect its personnel. Damage control, in its full meaning, is quite extensive and includes a wide field which covers many subjects and activities. Some of the major divisions are:

1. Stability and buoyancy.
   Watertight integrity.
   Ship construction and compartmentation.
   Hull strength.
   Piping, electrical, and other systems.
2. Fire fighting.
   Flooding control.
   Investigation of damage.
   Emergency repairs.
   Shallow water diving.
3. Operation of damage control equipment.
   Damage control communications.
   Casualty power and lighting.
4. Damage control safety precautions.
   First aid.
   Chemical warfare.
   Radiological warfare.
   Biological warfare.
5. Preventive maintenance.
   Allowance of damage control equipment.
   Allowance of damage control material and repair parts.
   Material inspections and records.
6. Damage control organization and training.

Damage control drills and battle problems.
Damage control competition and inspections.

The ship's damage control library consists of books, pamphlets, and publications which contain information or instructions necessary for the practical application of the theory of damage and casualty control. More detailed information on the list of publications may be obtained from the ship's damage control officers or by referring to chapter 88 (article 88–505) of BuShips *Manual*.

## APPLICATION OF DAMAGE CONTROL PRINCIPLES

In accordance with various directives from higher authority, the Damage Control Assistant and the damage control organization should impress upon all personnel the necessity for obtaining the highest degree of efficiency in the control of damage through the thorough understanding and application of damage control principles.

All leading petty officers and men of the damage control organization should obtain a working knowledge of the ability of the ship to resist damage and remain afloat. This knowledge is best obtained by a thorough study of the ship and its systems, and by the study of methods successfully used and of mistakes made by other ships in combating damage.

### Damage Control Books

Damage control books are restricted publications issued by BuShips to the individual ships. They contain material information in the form of text, tables, and diagrams concerning the construction, facilities, and characteristics of the ship. They also give information on complicated piping and electrical systems in connection with damage control. In general, these books will be of great aid in developing that detailed knowledge of the ship which is required before the proper damage control procedures or methods can be applied. Since there are many types and classes of ships in the Navy, general damage control procedures and training will have to be specialized for the particular ship in question.

## Ship's Organization Book

Every ship maintains a ship's organization book. It is made up under directives usually set down by the type commanders in the Standard Organization Book for ships of specific classes.

In the ship's organization book you will find information and orders for the routine organization and procedures on board ship. In addition, you will find the organization and procedures in case a special or emergency condition occurs. The latter is made up in the form of bills. Some of these bills are as follows: Cleaning, Maintenance, and Repair Bill; Battle Stations (including various conditions); Fire Bill; Collision Bill, Abandon Ship Bill, Fire and Rescue Bill; Salvage Bill; Special Sea Detail Bill; Jettison Bill; Scuttle Ship Bill; Gas Defense Bill; Radiological Safety Bill; and Darken Ship Bill. Since some form of damage control is connected with most of these bills, you must familiarize yourself with the damage control information in the ship's organization book.

## Watch, Quarter, and Station Bill

Space is provided on the Watch, Quarter, and Station Bill for the assignment of men to billets under the provisions of many of the bills listed above. It will be the responsibility of each CPO to see to it that all the men in his gang know the duties and responsibilities of their billets on the Watch, Quarter, and Station Bill.

## Damage Control Bills

Damage control operating bills are prepared by all ships whether or not damage control books have been furnished, and the preparation of these bills should follow carefully the instructions contained in USF–82, *Damage and Casualty Control Manual*. These bills must be kept current at all times by modifications to suit any late alteration to hull, armament, or machinery, or any changes in complement.

Damage control bills should not only outline repair procedures but should also contain instructions for operating the various systems, in conformity with the designated material conditions of closure, so that the objectives of damage control will be best obtained. Damage control bills are important in organizing the ship for damage. Leading petty officers must understand these bills and be familiar with them, since effective training is based on adequate organization.

### Engineering Casualty Control Book

The Engineering Casualty Control Book is similar to the ship's organization book and the damage control bills in that it gives the organization and procedures in case of casualties or damage. Many of the damage control bills also appear in this book.

## ORGANIZATION FOR CONTROL OF DAMAGE

Although Navy ships may be large or small and of different types, the basic principle for damage control organization during battle conditions remains more or less standardized. Some organizations are larger and more elaborate than others, but they all function on the same fundamental principles.

A standard type damage control organization, suitable for large ships but to be followed by all ships as closely as practicable, includes the Damage Control Central Station and the following repair parties:

Repair 1 (deck, or topside, repair party)—1F, forward; 1A, aft; 1B, amidship.
Repair 2 (forward below deck repair station).
Repair 3 (after below deck repair party).
Repair 4 (amidships below deck repair party).
Repair 5 (main propulsion party).
Repair 6 (ordnance repair party)—6F, part of Repair 2; 6A, part of Repair 3.

Aboard carriers, there will be two additional repair parties:

Repair 7 (gasoline repair party).
Repair 8 (flight deck repair party).

These repair parties each have a specifically located headquarters and are further subdivided into patrols, units, or secondary groups. This permits dispersal of personnel and a wide coverage of the assigned areas.

### Damage Control Central Station

The Damage Control Central Station is the battle station of the Damage Control Assistant. It will be found in a central location and as well protected as possible. On a large ship, this station is manned by a group including a stability control officer, a casualty board operator, and a damage analyst. You will also find representatives of fuel oil, electrical, and ordnance groups; and telephone talkers who have the required background and one trained to receive, deliver, and record messages. Figure 9–1 shows a compartment used by the personnel of the Damage Control Central Station.

In any ship's damage control organization, arrangements are made for a designated repair station to take charge of damage control activities. Should this central station be destroyed or rendered unable to retain control, other repair stations, in designated order, take over these same functions. Provisions are also made for passing the control of each repair party and its operation down through the officers, petty officers, and nonrated men, so that at no time will any group be without a leader.

The purpose of Damage Control Central is to collect and compare reports from the various repair parties in order to determine the condition of the ship and the action that should be taken. The commanding officer is kept posted on the condition of the ship and on important corrective measures taken. Repair party reports are carefully checked so that immediate action can be taken to isolate damaged systems, and to make emergency repairs in the most logical manner. Graphic records of the damage are made on various damage

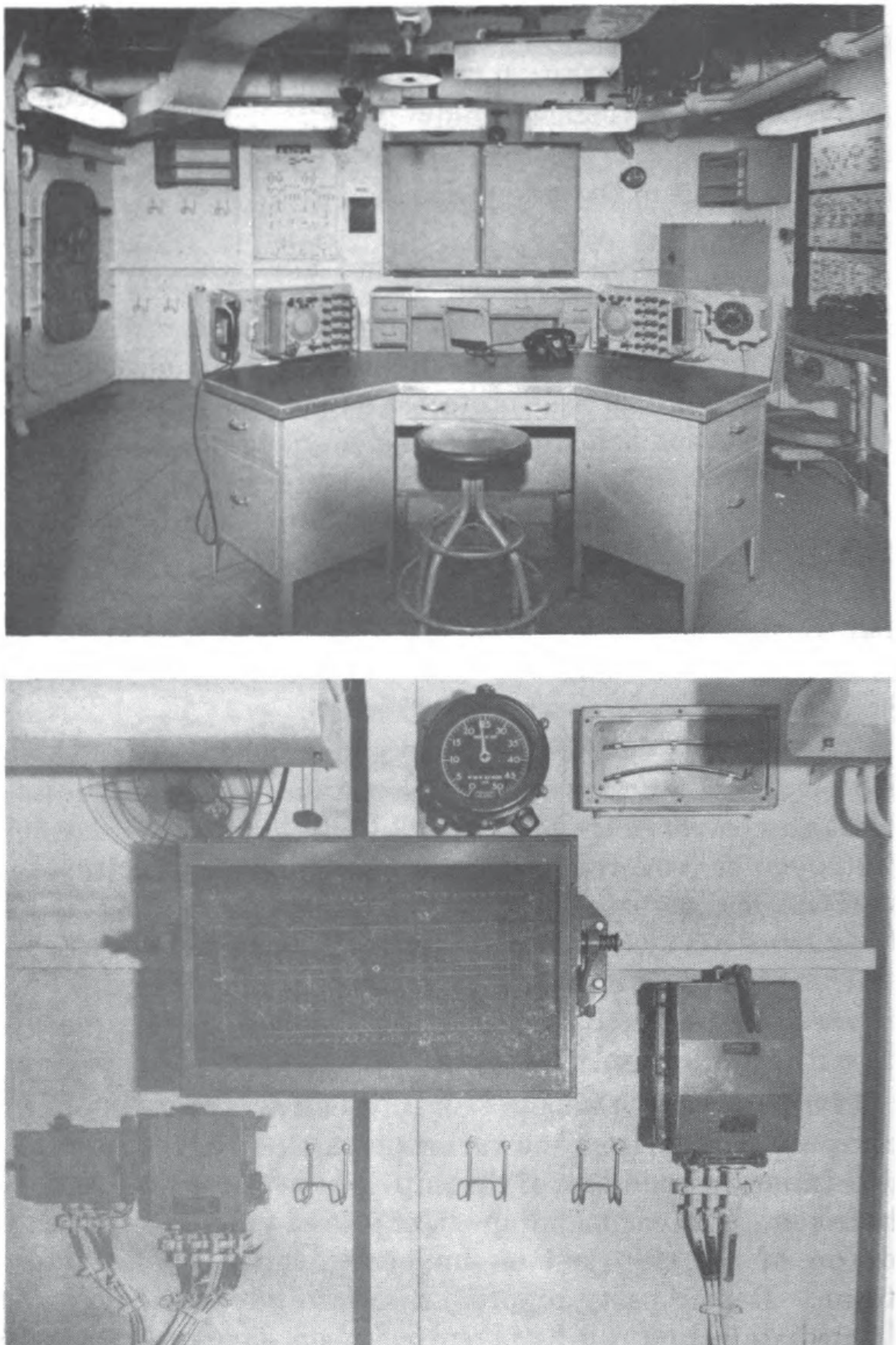

**Figure 9–1.—Damage Control Central Station.**

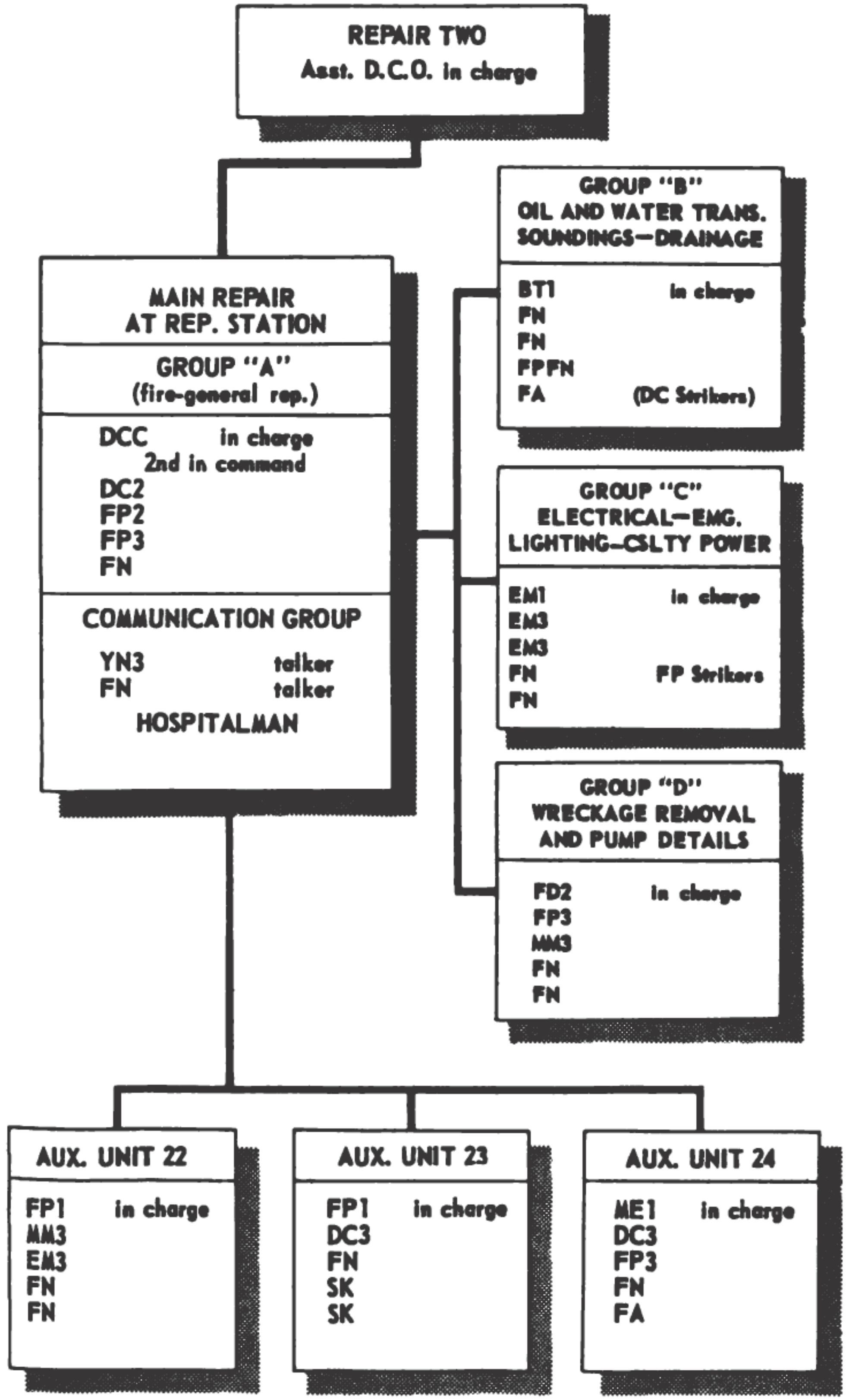


Figure 9-2.—A repair party complement (large ship).

control diagrams or status boards, as the reports are received. For example, reports concerning flooding are marked up, as they come in, on a status board which indicates liquid distribution before damage. With this information, the stability and buoyancy of the ship can be estimated, and the necessary corrective measures can be determined. Orders can then be sent for the required action.

A ship is a very complex structure and it would be practically impossible for an individual to learn all the details of the various systems, such as piping and ventilation, built into it. There must be some means of facilitating the locating of any part or section of these systems, and the section of the ship. This is especially true during an emergency. It is accomplished by means of diagrams that are kept at Damage Control Central and at the various repair party stations.

## Repair Party

The repair party is the damage control officer's representative at the scene of the casualty or damage. At his battle station, the damage control officer or his assistant is the nerve center and directing force of the entire damage control organization. (See fig. 9–2.) The orders and information given by the damage control officer cannot be all-inclusive, however, because many of his decisions must be delayed pending a complete and reliable estimate and analysis of the extent of damage, based on the receipt of accurate reports. These reports to a large extent come from the repair party in the affected area. The over-all effectiveness of the damage control organization is directly proportional to the effectiveness of the individual repair parties.

In distributing the available personnel to a repair station (see fig. 9–3), you will find that an engineering repair party will consist largely of Machinist's Mates, Machinery Repairmen, Boilermen, Enginemen, Firemen, and in many cases EM or IC ratings. The duties of EM and IC personnel include (1) making emergency electrical repairs on the scene, (2) directing the establishment of casualty-power connections,

Figure 9–3.—A repair party station.

(3) testing and locating damaged circuits, (4) restoring communication circuits or providing emergency means of communication, (5) providing the damage control repair or central station with information concerning the extent of electrical damage, and (6) making sure that the men assigned to the repair station are protected against electrical shock.

Repair parties assigned to areas in which magazines are located should have Gunner's Mates as part of their personnel. Storekeepers should be assigned to repair parties that have storerooms located in their areas.

The number and the ratings of men assigned to a repair party or station, as specified in the Battle Bill, are determined by: (1) the locale of the station, (2) the portion of

the ship assigned to that party, and (3) the total number of men available for all stations.

Many repair parties have auxiliary repair lockers at strategic locations in their assigned area to supplement the repair station's equipment. Figure 9-4 illustrates such a repair locker.

Each repair station will have an Officer in Charge, who may in some cases be a chief petty officer. The second in

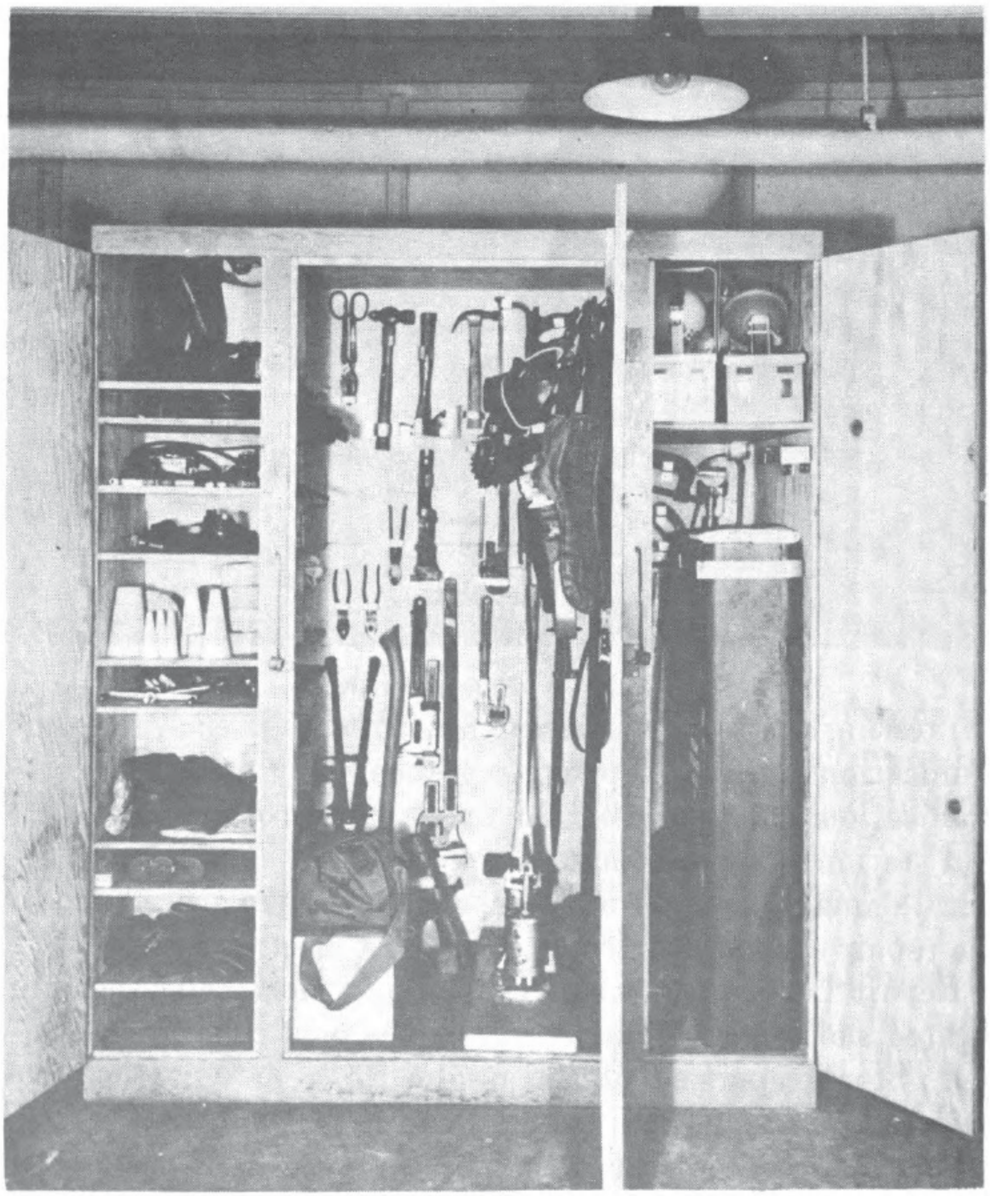

**Figure 9-4.—A repair locker.**

charge of a repair party is in most cases a chief petty officer who is qualified in damage control and is capable of supervising the repair party.

A set of operating instructions should be posted at each repair station. In general, these instructions will include the following:

1. Purpose of the repair party
2. Specific assignments of space for which that party is responsible
3. Instructions for assignment and stationing of personnel
4. Methods and procedures of communications
5. Instructions for handling machinery or equipment such as anchor windlass, steering gear, sprinkler systems, etc.
6. Functions of gas defense and the decontamination of personnel
7. Sequence of command and the procedure therewith
8. List of basic damage control drills
9. An inventory list of all damage control equipment and gear provided for the repair party

### Main Propulsion Party (Repair 5)

The main propulsion party is an integral and important part of the damage control organization. For that reason all personnel assigned to this repair party should be thoroughly familiar with the functions and responsibilities of the damage control organization. Large ships such as battleships and carriers have a main propulsion party designated as Repair 5. On smaller ships, Repair 2 usually serves as the main propulsion party.

Whether your ship is a carrier or a destroyer, the organization of your repair party is fundamentally the same, the principal difference being the number of men available. Inasmuch as it is not practicable to list the organization of the main propulsion party for the various types of naval vessels, the organization of a large aircraft carrier is used as an example.

Repair 5 is composed of a repair party headquarters and various groups or units. These groups or units are designated as follows:

| *Group designation* | *Location* |
|---|---|
| A1 | Forward auxiliary machinery repair. |
| A2 | After auxiliary machinery repair. |
| B1 | No. 1 fireroom repair. |
| B2 | No. 2 fireroom repair. |
| B3 | No. 3 fireroom repair. |
| B4 | No. 4 fireroom repair. |
| M1 | Forward main machinery repair. |
| M2 | After main machinery repair. |

The number of men available for the repair party will depend on the complement of the ship. The headquarters of the repair party is usually centrally located above the engineering spaces. However, in order to prevent all the men in the repair party from being destroyed by one hit, and in order to ensure that they will have ready access to all vital machinery spaces, the various Repair 5 units are dispersed throughout the area to which they are assigned.

For example, Group M1 would be stationed in the immediate vicinity of the No. 1 engineroom. The group leader should assign specific details to each man in the group. These instructions should include the responsibility for setting the proper material conditions of closure, and the care and maintenance of the damage control equipment assigned to the group. If you are responsible for assigning men to these details, always remember that they must know other phases of damage control in order to achieve maximum adaptability within the repair party.

After the proper material condition of closure ("Able" or "Zebra") has been set, the CPO in charge of each group should establish a patrol (composed of 1, 2, or 3 men, depending upon the personnel available). The patrol should have an accurate knowledge of existing conditions in the assigned area. Violations of the material conditions of readiness should immediately be reported. No doors, hatches, fittings, valves, or ventilation closures which are required to be closed

should be opened without proper authority. Maintenance of the proper condition of closure is the constant duty of the damage control patrol.

In addition to the patrol, personnel from the group should be assigned to remote control stations, in the assigned area, to operate valves for machinery, and other equipment located in the engineering spaces.

## Organization for Fire-Fighting

Repair parties provide the only personnel immediately available to fight fires during action. Other personnel, gun crews for example, must leave their primary duty should they have to fight a fire. It is essential that a plan of action embodying a systematic procedure for fighting fires be established. Loss of valuable time will be the inevitable result if the decision as to the method to be used in fighting a fire is not made immediately. Large repair parties may be divided into fire-fighting groups. In small ships, an entire repair party might be required to make up a complete fire-fighting group or "team." Where possible, at least two such groups should be organized from any one repair party. These groups should be trained so that any member can quickly undertake any of the detailed duties, as circumstances warrant.

Members of repair parties will generally be assigned to fire-fighting positions as follows:

1. Hose men (number determined by the size of hose).
2. Plug man.
3. Access men.
4. Foam generator operator.
5. Foam supply men.
6. Portable $CO_2$ men.
7. Oxygen breathing apparatus and asbestos suit men.
8. Tenders for men wearing breathing apparatus and asbestos suits.
9. Ventilation detail.

In smaller fire-fighting groups, one individual must necessarily perform more than one of the detailed duties. This

should be provided for when organizing the group. A fire-fighting group consisting of as few as four men can be effective. The senior rated man should be designated as the group leader. His first duty is to get to the fire quickly, then investigate and determine its nature, and supervise his team in fighting the fire. He must make decisions as to whether additional or different equipment is required and also as to the number of personnel required for fighting the fire. The analysis he makes must be in accord with the principles that are set forth in chapter 93 of BuShips *Manual*, and taught at the Navy fire-fighting schools.

Although fire fighting is one of the most important functions, the repair parties have other duties for which they must organize and train. Some of these are chemical warfare defense, radiological defense, biological defense, investigation of damage, shoring, etc.

## DAMAGE CONTROL COMMUNICATIONS

Damage control communications is of vital importance to the damage control organization. Without adequate means or proper procedures of communications between the different units of the damage control organization, the whole organization would break down and fail in its primary functions. Therefore, proper organization and procedures for damage control communications cannot be overemphasized.

It is impractical to cover in detail all types of ships in describing communication systems. Figure 9–5 covers only the IC systems found on large combatant ships. A general knowledge of these systems, however, will promote better understanding of the other systems in use in smaller ships.

The normal means of damage control communications aboard large ships are:

1. Battle telephone circuits (sound-powered).
2. Interstation 2-way systems (4MC intercoms).
3. Ship's service telephones.
4. Ship's loud-speaker system (1MC general announcing).

5. Voice tubes (where installed).
6. Messengers.

### Battle Telephone Systems

The battle telephone systems are sound-powered circuits. They require no outside source of electric power. The transmitter of the sound-powered telephone is an instrument designed to transform sound waves into electrical energy. The receivers are capable of converting this electrical energy into similar sound waves. Outlets for sound-powered battle telephones are located at numerous critical locations throughout the ship.

The normal damage control sound-powered circuits are:

| | |
|---|---|
| 2 JZ | Damage and stability control. |
| 3 JZ | Main deck repair 1. |
| 4 JZ | Forward repair 2. |
| 5 JZ | After repair 3. |
| 6 JZ | Amidships repair 4. |
| 7 JZ | Main propulsion repair 5. |
| 8 JZ | Flight deck repair (carriers only) 8. |
| 9 JZ | Magazine sprinkling and ordnance repair, forward 6F. |
| 10 JZ | Magazine sprinkling and ordnance repair, aft 6A. |
| 3 JG | Aircraft service (carriers only). |
| 5 JG | Aviation ordnance (carriers only). |
| 7 JG | Conflagration control (carriers only). |
| JA | Captain's battle circuit. |
| 1 JV | Maneuvering, docking, and catapult control. |
| 2 JV | Engineer's circuit (engines). |
| 3 JV | Engineer's circuit (boilers). |
| 4 JV | Engineer's circuit (fuel and stability). |
| 5 JV | Engineer's circuit (electrical). |
| JL | Lookouts (surface and sky). |

A schematic arrangement of the damage control telephone systems on a large ship is shown in figure 9–5.

THE JZ SOUND-POWERED CIRCUITS. The 2 JZ sound-powered circuit is common to the Damage Control Central Station and to all repair parties. (See fig. 9–5.)

The 3, 4, 5, 6, and even 7 JZ circuits are individual repair party circuits, connecting each repair party station with its auxiliary station and patrol areas. Each of these repair

party circuits has an outlet in the Damage Control Central Station, either through a selector switch or individual jack boxes, or both. The latter is preferable and permits the manning of each circuit by individual talkers.

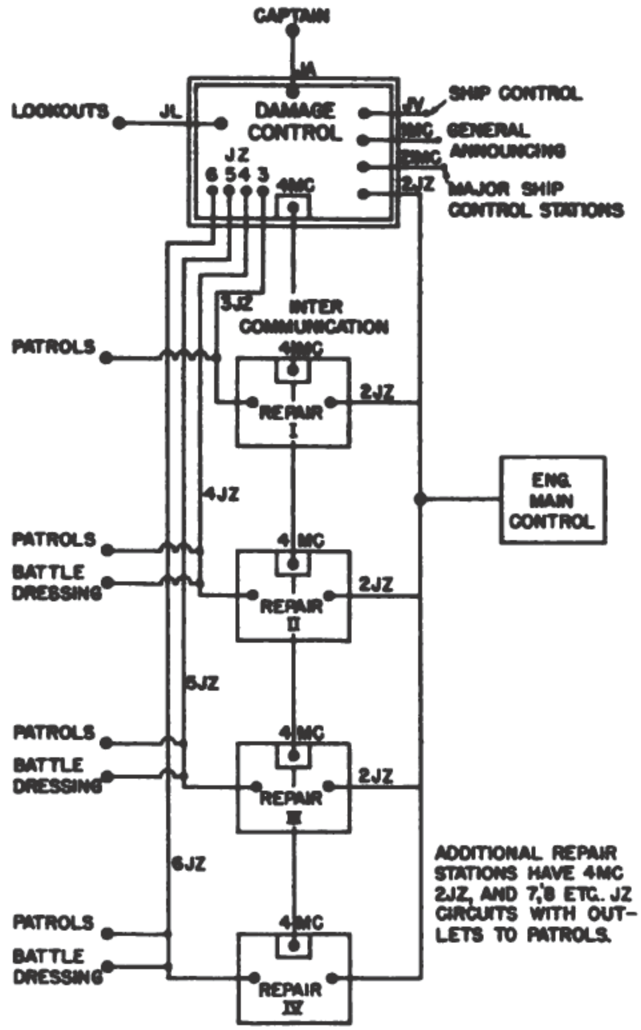


**Figure 9–5.—A damage control interior communication plan.**

Where individual manning is done, the 2 JZ circuit is preferably used as an outgoing circuit from the Damage Control Central Station, carrying information and orders from the Damage Control Assistant to the various repair party stations. Each individual repair party circuit (3, 4, 5, 6, and 7 JZ) thus becomes an incoming circuit into the Damage Control Central Station. This automatically makes the Damage Control Assistant, through any of his talkers,

either an "information or an action addressee" on any messages carried over any individual repair party circuit.

Aboard smaller ships where only a single circuit is available, both incoming and outgoing messages must be handled over the same circuit.

EMERGENCY COMMUNICATION. On a ship having a minimum length of 200 ft, circuit X40J is installed to provide emergency communication between the open bridge, main engine control, damage control, and the steering gear room. Permanent risers are installed port and starboard from the main engineroom to double jackboxes located about 3 feet above the main deck. An identical installation from the steering gear room to the main deck aft is provided. Portable cables fitted with jackboxes and plugs are provided for interconnecting the riser jackboxes with each other and to a telephone headset. The wire provided is a special portable wire that may be passed through watertight doors and hatches without destroying watertight integrity.

AUXILIARY CIRCUITS. Most ships have auxiliary circuits which are, for all practical purposes, duplicates of the primary circuits. These circuits serve the same stations as are served by vital primary circuits.

STRING TYPE CIRCUITS. String circuits are a third type of sound-powered circuit in most ships, and are installed in stations not especially vital to ship operation. They are installed in such locations as between the upper and lower handling rooms of 5″ mounts, turret stations, topside radio, radar and direction finder stations. Although these circuits are not normally used for damage control purposes, their existence in stations or sections of the ship not served by damage control circuits must not be forgotten, as in emergencies they may be tied in to primary circuits in order to extend communications to a remote section.

## Other Means of Communication

INTERCOMMUNICATING UNITS. Systems of recent design employ the intercommunicating units (circuit 4MC) on the damage control announcing system. These units provide a

dependable and fast 2-way transmission of damage control orders and information between the Damage Control Central Station and each repair station. A 1-way communication is provided from each repair station to each repair party area served by that station by utilizing satellite reproducers.

Ship's Service Telephones. On many ships these are available for use where they are installed at or near repair stations. Too much reliance should not be placed on them as they are not part of a rugged battle system and may go out of commission early in action.

Ship's General Announcing System. This system (1MC) is a means of communication, but so many stations other than damage control are affected that it is not desirable to use it unless all other methods fail. It should be reserved for warnings or for information that vitally affects the entire ship's company.

Messenger Service. Each repair party should include personnel trained as messengers for relaying orders and information. A written message is always more reliable than an oral message. However, messengers should be trained to carry oral orders without error.

### Control of Telephone Circuits

Wherever possible, an outgoing line should be on a separate circuit from an incoming line; if one circuit is used, the resulting confusion will greatly increase the difficulties of getting information through correctly and speedily.

It is imperative that control of a circuit be established by the major controlling station so that an orderly flow of communication may be obtained. The circuit must never be allowed to get out of control as a result of the "cross-talk" which exists when 2 or more stations assume priority of messages. The controlling station must be able to clear the circuit immediately and establish a priority for messages whenever the need arises.

Succession of Repair Stations to Control. The chain of succession of repair party stations to main control must be

so well established that it will serve as a permanent plan in case the Damage Control Central Station is destroyed, or temporarily put out of commission.

Damage Control Central, by not answering to communications, may simulate being out of commission. This provides a test of the organization and procedures of the station designated to assume command; and the efficiency and speed with which repair parties take over control can be noted. The next station in the chain of control, by testing at regular intervals, should soon discover that Damage Control Central is "out," if they can communicate with other repair stations and cannot contact Damage Control Central by any means of rapid communication. They should then take over the control and notify all other repair stations, the commanding officer, and main engine control that they are doing so. This information must be positive and there must be no doubt who has control for damage. After the second station has assumed control, an investigation party should be sent to Damage Control Central Station. This procedure should be followed until all stations have succeeded to control for damages and have exercised this control properly. Damage Control Central can always restore control by saying "Damage Control Central taking over control," and receiving proper acknowledgments.

This drill should emphasize the necessity for keeping written logs of all information and orders given by Damage Control Central whether it applies to the specific station or not. In the event a repair station succeeds to control for damage, it must know what casualties all other stations are handling in order to assume control intelligently.

Damage Control Communication Bill. The organizational details of damage control communications should be written up in the form of a bill so that they will be readily understood and followed by all damage control personnel. These details should include such items as: (1) succession to main control, (2) primary circuits and stations to be manned, (3) procedure for shifting to secondary circuit in case of failure of the primary circuit, (4) procedure for

clearing damaged circuits by means of cut-out switches, (5) rigging of emergency communications, (6) policies regarding priority of messages and what information should be sent on each telephone circuit, (7) standard phrases and practices to be used, (8) rules for talkers, care of telephones, and (9) other items suitable for the control of damage for the ship concerned.

It is also recommended that this bill should list alphabetically the ship's interior communication circuits, and the location of their outlets. Then, in addition, a list can be made of each station or compartment, showing the various circuit outlets installed at these stations. This will greatly facilitate setting up emergency, auxiliary, or extended communications.

Telephone Control Stations. At these stations are located the action cut-out switches for clearing the battle telephone systems in case of damage or short circuits. On large ships, this isolation may be accomplished by means of action cut-out switches found in the controlling station of each circuit or on the main telephone switchboard in interior communication rooms. In these installations both stations may take the action necessary to isolate short-circuited portions of a circuit, thus restoring the remainder of the circuit to use. These action cut-out switches whenever provided are the best protection against total and continued lack of communication if their operation and importance are fully recognized. The damage control communication bill and organization for use of alternate circuits, in the event of damage entailing loss of communication on primary circuits, will recognize the importance of action cut-out switches and their locations. The talker who has this cut-out switch at his station will have control of the entire battle telephone circuit.

Flexibility of Damage Control Communications. The flexibility of the communications on which damage control organization depends for its reports, orders, and information has been demonstrated in action. Although improvements

have been made in this respect, the danger of organizational failure must be guarded against. The various methods of communication between vital parts of the ship should be thoroughly understood so that, if the line of communication normally used becomes damaged (and cannot be cleared up), available alternative lines of communication can be readily placed in operation. This procedure must be clearly understood by all damage control telephone talkers, or confusion will result and the damage control organization will break down. Frequent drills where circuits are actually shorted without warning should be held to test the flexibility of damage control communications. All lines of communications should be tested periodically by IC maintenance personnel.

## Damage Control Reports During Action

Reports by Patrol and Investigators. Patrols and other investigators should make their reports to the officer in charge of their respective repair party station; he will coordinate the information and pass it along to the Damage Control Central Station. Portable sound-powered telephones are invaluable for maintaining communication between the scene of a casualty and the repair party station.

Reports From Repair Parties. The most dependable source of information will be the repair parties investigating at the scene of damage. Repair party personnel should be trained to make prompt, accurate reports to the Damage Control Central Station.

It will be necessary to make several reports when damage is inflicted. The initial report should contain the following information:

1. Nature of damage (class B fire, bomb hole, ruptured firemain, etc.)
2. Location of damage (deck, frame number, athwartship position relative to centerline—i. e., port, starboard, or centerline—and compartment number)
3. Extent of damage (flooding—approximate gpm; fire—smoke or toxic gases present)

4. Measures being taken to combat damage (investigation still in progress; fire fighting—number of hose, size of hose, type of extinguishing agent and method of application; dewatering compartment—number and types of pumps being used)

5. Assistance required

This report must be made as soon as possible and any information which cannot be contained in the initial report should be made in subsequent reports. These reports are made to Damage Control Central for the primary purpose of keeping the Damage Control Assistant posted, in order that he can recommend such action as will not only assist your repair party but also be best for the over-all safety and stability of the ship.

Typical reports for fire in a living compartment would be as follows:

INITIAL REPORT:

Damage Control Central, Repair 2, Class Able Fire, 3rd Deck, Frame 80, STBD Side, Compartment A–309–L.

Two salt-water hose teams attacking fire with high velocity fog and solid stream.

Unit hose teams are entering surrounding compartments to cool down bulkheads.

SECOND REPORT:

Damage Control, Central, Repair 2, Class Able Fire, 3rd Deck, Frame 80, STBD Side, Compartment A–309–L under control.

Unit hose teams are cooling down bulkheads in surrounding compartments.

THIRD REPORT:

Damage Control Central, Repair 2, Fire Out, 3rd Deck, Frame 80, STBD Side, Compartment A–309–L.

Flash back hose team has been stationed. Compartment being ventilated. Dewatering of compartment in progress, using one P–500.

Damage Sustained—20 bunks burned; no personnel casualties.

FOURTH REPORT:

Damage Control Central, Repair 2, secured flash back hose team from compartment A–309–L, 3rd Deck, Frame 80, STBD side.

Completed dewatering compartment.

Cause of fire not determined.

REPORTS OF DAMAGE CONTROL CENTRAL. The damage control officer must ascertain from the commanding officer what information he desires with regard to extent of damage and corrective measures, how detailed it should be, what circuits it is to be supplied over, and when. The question of "when" involves what the CO wants to know while the action is still in progress, and what information is to be withheld until after the action is broken off. Key personnel should be indoctrinated in the procedure established. Usually a brief summary and corrective action taken in regard to damage, fires, flooding, buoyancy and stability, speed available, reductions in gun-power, and probable results of the casualty are transmitted to the bridge and relayed to the commanding officer.



CONDITIONS AFFECTING REPORTS. When general quarters is sounded, for drills or before action takes place, the normal reports of stations being "manned and ready," and checking of communication circuits for proper operation are made; periodic checks are made to be certain that all parties are on the line.

When a single hit or casualty occurs, the major part of communications is the flow of information and orders from the repair party concerned and Damage Control Central.

The difficulties in communication become apparent when there are numerous hits or casualties throughout the ship. All the repair parties will be trying to send information to Damage Control Central at once. Communication circuits will become overloaded and jammed unless the proper procedure and control are maintained. Training and frequent drills are invaluable in this respect. A policy of priority of different types of messages should be well established. Messages of vital information or those that require immediate

action of some other damage control unit should be sent first. When these have been transmitted, other important messages or reports should be sent. Routine messages and those of little importance should be held up until all others have been transmitted and lines are free. Usually, these messages or reports are held over until there is a lull period when no action is taking place. The damage control communications bill should give the priorities of reports and information of various types. This should be well understood by damage control communication personnel and by personnel directing damage control activities.

## DUTIES OF PETTY OFFICERS IN A DAMAGE CONTROL ORGANIZATION

The MMC or MM1, when not assigned to an engineroom, may be a logical candidate for a repair party battle assignment. The repair party assignment is not the same as a permanent one in an engineroom; but because of the MM's mechanical ability, knowledge of piping systems and auxiliary machinery, and miscellaneous repair experience, he should be able to quickly adapt himself to the various damage control functions. Also, he may have had considerable damage control instruction and experience when he was MM3 or 2. When a petty officer, regardless of his rate, is assigned to a damage control organization during battle conditions he must be able to perform the required damage control duties. To some it may appear to be a temporary or additional assignment. But it must be remembered that the control of damage is a vital function and may mean the difference between losing or saving a ship.

### Know Ship's Damage Control Organization

An MM1 or C assigned to a repair party as his battle station must understand thoroughly the damage control organization on his ship. If in doubt he should see the Officer in Charge of the repair party or the Damage Control Assistant for the necessary information or instructions. He

must understand the organization for damage control and be familiar with damage control procedures.

The leading petty officer of a repair party must be familiar with and review as necessary, the Ship's Organization Book, ship's damage control bills, ship's Damage Control Book, damage control diagrams, BuShips *Manual* (chapters 88 and 93), and other material pertinent to damage control and its organization.

If assigned to a repair party he must clearly understand its organization and how its various functions are carried out. Also, he must have a general knowledge of location and duties of the other repair parties, including Damage Control Central Station. The knowledge of the various units and of how they work together to form the damage control organization is most important to supervisory personnel.

### Make the Organization Function Properly

The best damage control organization is of no practical value if it exists only on paper. Its proper functioning depends upon the officers, chief petty officers, and leading petty officers in the organization. Knowledge, leadership, and training are some of the basic requirements for leading and supervisory personnel in any organization.

Besides the knowledge of fundamentals, the leading petty officer must see to it that the proper organizational procedures are carried out where groups of men are involved in such phases of damage control as fire fighting, flooding control, damage control communications, etc. He should correct and supervise personnel with the aim of obtaining a smooth-running and efficient organization.

### Be Able to Take Over Leadership

In the Navy a man is always preparing himself for advancement by studying and becoming proficient in the practical requirements for the next higher rate. The same principle holds true for personnel in a damage control organization. The second senior man should be able to take

the leading man's job of a partial or of a complete repair party. In a battle engagement the officer or key petty officer may be injured. To prevent confusion or disorganization, the second in charge of a unit, or repair party, should be able to take over the leadership.

Another condition may arise when the ship is in port. A fire, collision, or casualty may occur when only the duty section is on board. Many of the key personnel of the damage control organization will be away from the ship, and it will be the duty of those on board to carry out the proper procedures of controlling damage or extinguishing fires. Although those men assigned to the damage control organization under normal conditions will man their battle stations when fire call is sounded, it may be necessary to call upon others, not familiar with this location as their regularly assigned battle station, to assist in extinguishing a fire. Good leadership will be needed, therefore, to use available personnel to the best possible advantage. If this leadership is not provided, general confusion and disorganization may result, with little or no effective corrective measures being taken. Too many men congregating at the scene of casualty may also create confusion. Personnel not needed should be cleared from the scene of action and stationed at a location where they may be promptly called as conditions may require.

### Training of Personnel

As a chief or first class petty officer you may be charged with supervision of all or part of a repair party station. Inasmuch as the success of battle repair depends, in part, on knowledge and speed, the element of time does not allow for detailed supervision at the scene of the casualty. For this reason, during routine drill or training periods, one must train men so that it will not be necessary to give detailed supervision when actual casualties or damage occur.

Training of personnel in damage control subjects may be accomplished by methods such as the use of training film, training aids, training mock-ups, lectures, and demonstrations. Men are taught by actual operation and use of all

damage control equipment and material. Fundamental drills and complicated battle problems are held. As a leading petty officer assigned to a damage control organization, you may be required, under the supervision of the Damage Control Assistant, to supervise and train men. Much of this training will take place when the ship is drilled at general quarters. As in any "team," training must begin with the individual and should stress fundamentals.

An outline for training will prove important in developing a good "team." The following is a typical training outline:

1. Material Conditions of Readiness.
   - a. Setting Material Conditions.
   - b. When Conditions Are Set.
   - c. Setting Material Conditions On:
     - (1) Firemain.
     - (2) Ventilation.
     - (3) Piping and Drainage Systems.
2. Damage Control Equipment.
   - a. Pumps:
     - (1) P–500.
     - (2) Handy Billy.
     - (3) Submersible Pumps.
     - (4) Gasoline Fire Pumps.
     - (5) Eductors.
   - b. Emergency Repair Equipment:
     - (1) Portable Cutting and Welding Outfits.
     - (2) Portable Blowers.
     - (3) Electrical Tools.
     - (4) Velocity Power Tools.
     - (5) Screw and Hydraulic Jacks and Chain Falls.
   - c. Emergency Protection Equipment:
     - (1) Oxygen Breathing Apparatus.
     - (2) Hose (Air-Line) Masks.
     - (3) Gas Masks.
     - (4) Asbestos Suits.
     - (5) Chemical Defense Protective Clothing.
     - (6) Shallow Water Diving Equipment.

d. Detection Equipment:

(1) Explosimeter.

(2) Flame Safety Lamp.

(3) Chemical, Biological, and Radiological Detectors.

e. Fire Fighting Equipment:

(1) Hose and Fittings.

(2) High-Capacity Fog-Foam System.

(3) Continuous-Type Foam Generators.

(4) N. P. U. (Navy pick-up) Nozzle and Foam.

(5) Installed $CO_2$ Systems.

(6) Portable $CO_2$.

(7) Steam Smothering.

(8) Sprinkler Systems.

3. Interior Communication.

a. Sound-Powered Phones.

b. Secondary Communication Equipment:

(1) 4 MC.

(2) 1 MC.

(3) Ship's Service Telephones.

c. Primary and Secondary Sound-Powered Circuits.

d. Emergency Communication Circuits.

e. Priority of Circuits.

f. Relationship of Repair Party Communication to Damage Control Central.

4. Operational Procedures.

a. Methods of Fire Fighting:

(1) Class A.

(2) Class B.

(3) Class C.

b. Radiological, Biological, and Chemical Warfare Defense:

(1) Gas Detection and Identification.

(2) Monitoring and Decontamination.

(3) Self-Aid and First Aid.

c. Deck Machinery.

d. Steering Machinery.

e. Air Compressors.
f. Applying First Aid.
g. Shoring.
h. Dewatering Compartments.
i. Emergency Cutting and Welding.
j. Applying Emergency Patches.
k. Maintaining Stability Through Counterflooding.

To the above outline there could be added a list similar to the one shown earlier in this chapter, under the section "Knowledge Necessary for Damage Control." The non-rated or new man in a damage control organization should have a basic understanding of the subject of damage control and why he must be competent in the use and operation of damage control equipment.

The leading petty officer in charge of a detail or a repair party is in an excellent position to know the weak and strong points of his "team," and thereby determine what types of drills or training should be conducted. This knowledge of his men will be of aid to the Damage Control Assistant in setting up a training program and various drills.

In conducting drills and training, precautions must be taken to avoid having or establishing "key men" in the organization. These men may become injured and the resulting loss will cause confusion. If a man or petty officer is an outstanding leader of a hose party, simulate his injury and let the next man take over. Men should be rotated in their duties. As far as practicable, a man should be versatile and a jack-of-all-trades; and the organization should be kept flexible.

One of the qualities of good leadership is to be able to instill interest and competition among the men in damage control drills and activities. This may not prove as easy as it sounds, because during drills one does not have the actual holes and flooding or fires burning on board ship. To simulate fires, damage, and flooding is one of the most difficult aspects of damage control training and should be given a great deal of thought. Smoke flares and red pieces of canvas

can be used to represent fires; chalk marks and blue pieces of canvas or training mock-ups can be used to imitate flooding and holes in the ship; red rags and shipping tags can serve to indicate personnel injuries; shorting-out plugs can be placed in damage control telephone circuits; large tags or training mock-ups can be used to simulate breaks or holes in piping; and posters of various types can give information on damage.

A logical sequence should be followed in training men in a certain drill or subject. First, a lecture should be made to give men the purpose and importance of the drill. They must have a clear understanding as to what it is all about. Have the men walk through the drill, in order to check for proper procedure; later, speed can gradually be developed. Do not sacrifice quality for speed. Remember that speed in doing a drill comes last. Unless this training procedure is followed, confusion will result and some men may never completely learn the drill.

Ordinarily, all the fundamental drills should be properly held and completed before a complicated battle problem is attempted. The purpose of the battle problem is to train the damage control organization as a whole unit and to locate weak points. It is similar to the final examination after a course of study has been completed.

Do not forget the telephone talker. There are important communication drills and training that must be completed before he is ready for a battle problem, otherwise the whole top level of the damage control organization will break down. Remember that a complete prearranged battle problem can be simulated by the communication personnel under the supervision of one officer or petty officer at each station. This training of the telephone talkers can take place independently of any drill for the damage control organization as a whole unit.

## SUMMARY

Damage control is one of the most important elements of your shipboard life. In addition to the billet assigned you in your division, you have duties as a member of the damage

control organization. As an MM1 or C, you will be a leading petty officer of a repair party, and in some cases you will have charge of a repair party.

The objectives of damage control are (1) to take preventive measures before damage is inflicted, (2) to minimize and localize damage, and (3) to accomplish emergency repairs. In order to attain its objectives, the damage control organization depends on men who have a detailed knowledge of ship construction, compartmentation, ship characteristics, and stability.

To assist you in carrying out your duties as a member of a repair party, many publications are provided as a source of damage control information. The principles and procedures to be followed are stated in chapter 88 of BuShips *Manual*. Selected registered publications (the Damage Control Book, Ship's Organization Book, Casualty Control Book, etc.) are available aboard ship. Practical illustrations of the application of casualty procedures can be found in War Damage Reports.

The damage control organization consists of Damage Control Central and repair parties. Each repair party is assigned an area of the ship and is responsible for damage control in that area. Damage Control Central coordinates the activities of all repair parties for maximum effectiveness.

The sound-powered circuit is the most important means of communication between each repair party and Damage Control Central. The success of any communication system depends on well-trained telephone talkers, and repair party personnel who transmit accurate and pertinent information through the telephone talkers.

# QUIZ

1. What is the backbone of shipboard damage control?
2. What are the two types of shipboard organization?
3. What are the three basic objectives of shipboard damage control?
4. Why must damage control be considered as an offensive as well as defensive function?
5. How can leading PO's and men of the damage control organization get a working knowledge of the ability of their ship to resist damage and remain afloat?
6. Where can you obtain detailed information concerning publications on damage control?
7. What must you read in order to fully understand the organization of the ship in regard to damage control?
8. Why are repair parties subdivided into patrols, units, or secondary groups?
9. Where is the Damage Control Central Station usually located?
10. What is the purpose of Damage Control Central?
11. Who represents the Damage Control Assistant at the scene of a casualty?
12. In order to help you locate any section of the ship, or of the ship's systems, what source of information is available on board ship?
13. The over-all effectiveness of the damage control organization is directly proportional to what?
14. What factors determine how many men and of what ratings will be assigned to a repair party or station?
15. Upon what factor does the number of men available for the Repair 5 party depend?
16. What is the primary duty of the damage control patrol?
17. In addition to regular repair party duties, personnel should be assigned to patrols and what other duties?
18. Under battle conditions, what personnel will be immediately available to fight fires?
19. What are the normal means of damage control communications aboard large ships?
20. What sound-powered circuit is common to the Damage Control Central Station and all repair parties?
21. Which individual repair party circuits connect each repair party station with its auxiliary station and patrol areas?

22. On a ship having a minimum length of 200 ft, what circuit is installed to provide emergency communication between the open bridge, main engine control, damage control, and the steering gear room?
23. Why is it not practical to rely on ship's service telephones for damage control communications?
24. Why is it not desirable to use the 1MC system for damage control communications?
25. Why must each repair station keep a written log of all information and orders given by Damage Control Central, even if it does not apply to the specific station?
26. What is the function of action cut-out switches found in telephone control station circuits?
27. What are 3 basic requirements for supervisory personnel in any organization?
28. In order to prevent confusion in a repair party, who should be able to take the leading man's job of a partial or of a complete repair party?
29. In conducting drills and training, why must precautions be taken to avoid having "key men" in the damage control organization?
30. How can casualties in damage control telephone circuits be simulated?

CHAPTER 10

# DISTILLING PLANTS

This chapter deals primarily with abnormal oper conditions, trouble shooting, and repair of distilling pl In order to trouble shoot, or to quickly recognize abno operating conditions, an MM1 or C must have a good p tical knowledge of a distilling plant. This knowledge only be obtained from study and from practical operat such as standing evaporator watches. As far as practic all Machinist's Mates should have watch standing experie and be capable of operating a distilling plant. An M or C must also have a good knowledge of normal operat conditions in order to recognize different types of troub which, in turn, produce certain abnormal operat conditions.

The discussion of distilling plants, in this chapter, w emphasize items of a general nature. For detailed inform tion, you must study the manufacturer's instruction bo for the particular type of plant on board your ship.

## GENERAL TYPE PLANTS

The installations of the low-pressure submerged-tube typ of distilling plant will vary for different ships, but, in al cases, the operating principle is the same. The information in this chapter deals with the two general type plants shown in figures 10–1 and 10–2. Figure 10–1 shows a plan of a distilling plant consisting of one triple-effect unit. Two such units are often installed aboard ship.

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For purposes of review, the piping system of the low-pressure submerged-tube type of distilling plant may be divided into 7 different circulating systems, as indicated by the following circuits:

1. Generating steam.
2. Vapor.
3. Fresh water.
4. Air removal.
5. Condenser circulating water.
6. Evaporator feed water.
7. Brine.

These circulating systems, together with the necessary vent and drain connections to the various units of the plant, make up the complete piping system.

The distilling plant shown in figure 10–1 is generally known as a "three-effect" or "triple-effect" plant. Some of the 20,000 gpd plants, and all the 30,000 and 40,000 gpd installations, are of this type. All smaller plants (4000, 8000, 10,000, and 12,000 gpd) and some 20,000 gpd plants are built for two-effect or "double-effect" operation. Figure 10–2 shows a typical diagrammatic arrangement of a double-effect low-pressure distilling plant.

The double-effect plant differs from the triple-effect plant in the following respects:

1. No evaporator feed pump is used. With the shorter feed circuit, a comparatively slight increase in the pressure setting of the spring-loaded back-pressure valve provides sufficient head to deliver the sea-water feed to the first-effect shell.

2. Evaporation takes place in two stages rather than in three. The third-effect shell of figure 10–1 becomes the second-effect shell of figure 10–2. The second-effect shell and flash tank of figure 10–1 are omitted in figure 10–2.

## OPERATING TROUBLES AND REMEDIES

Careful operation and proper preventive maintenance procedures will, to a great extent, ensure trouble-free operation of a distilling plant.

The operation of the distilling plant is normally taken c of by the watch standers, under the general supervisior an MM1 or C. When operating troubles occur, it will the responsibility of the MM1 or C in charge of the distill plant to locate the trouble and to make the necessary cor tions or repairs.

Failure to obtain full rated capacity of the plant is one the most frequent troubles encountered during the operat of a distilling plant. This trouble is most difficult to rem since it may result from a combination of any number factors. The various factors which promote full output the distilling plant are as follows:

1. Proper steam pressure above the orifice.
   a. Ample steam supply.
   b. Proper operation of the reducing valves.
2. Highest possible vacuum in the first-effect tube ne
   a. No air leaks.
   b. Proper water levels in the evaporator shells.
   c. Evaporator tube nests continuously vented.
   d. Evaporator tube nests reasonably clean:
      (1) Continuous feed treatment and periodi chill-shocking.
      (2) Tubes mechanically cleaned when necessary
      (3) Density of brine overboard not over 1.5/32
         (a) Overboard piping reasonably clean
         (b) Proper valve settings.
         (c) Proper operation of brine pump (clean suction piping and strainers proper speed and direction of rotation; pump properly vented; gland properly packed and sealed; no air leaks in pump piping).
   e. Evaporator tube nests properly drained:
      (1) Proper operation of all drainers.
      (2) Proper operation of the tube nest drain pump.
3. Highest possible vacuum in the last-effect shell.
   a. No air leaks.

Fuel handling pl

b. Proper air ejector operation:
   (1) Clean nozzle and strainer.
   (2) Sufficient pressure and dry steam at nozzle.

c. Ample flow of circulating water:
   (1) Clean strainer, pipe line, and tubes.
   (2) Proper valve settings.
   (3) Proper operation of the circulating pump.

d. Effective surface in the distilling condenser:
   (1) No undue deposit inside the tubes.
   (2) Proper venting of the condenser tubes.
   (3) Proper operation of the condensate pump.

The above outline indicates the manner in which the listed factors affect not only one another but also the over-all performance and the output of the plant. The location of the factors in the above outline does not necessarily indicate their relative importance. For example, improper operation of the condensate pump may affect the output directly (in addition to affecting the condenser vacuum), since undrained distillate will decrease the condensing surface in the distiller condenser, thus affecting the vacuum; or, in some plants, it may spill back into the last effect and be re-evaporated.

### Evaporator Steam Supply

It is self-evident that a full output cannot be maintained unless steam in the normal amount and at the proper pressure is supplied to the plant. The orifices supplied are designed to pass the proper amount of steam to permit rated capacity operation with a pressure of about 5 psi gage above the orifice. It is recommended that the orifice be inspected annually. A measurement of the orifice should be taken and compared with the figure stamped on the orifice plate. If necessary, the orifice plate should be renewed.

Any variation of steam pressure above the orifice requires an investigation, first of the weight-loaded regulating valve, and then of the pressure-reducing valve (if installed), to determine whether or not the valves are operating properly. If they are functioning properly and the pressure cannot be

maintained above the orifice, an insufficient amount of steam is being supplied to the plant.

A small amount of superheat in the exhaust steam supply has little or no effect on the operation nor on the scale formation but, regardless of the first-effect tube nest pressure used, temperatures in excess of 245° F should be avoided to prevent formation of hard scale. The desuperheater water spray should be checked, if necessary, to ensure that it is operating properly.

## First-Effect Tube Nest Vacuum

Current operating practice for plants establishes that a pressure maintained in the first-effect tube nest must be within the range of from 16 inches Hg vacuum, with clean tube bundles, to about atmospheric pressure, with scaled tube surfaces. If the plant is in a satisfactory operating condition, the heating surfaces will be adequate to ensure 100 percent of rated capacity within the above pressure range. With the vacuum in the first-effect tubes maintained as high as possible, scale formation will be kept to a minimum and the plant will be able to operate at full capacity. Reference to the outline given earlier in the chapter shows that the primary factors affecting the first-effect tube nest vacuum are: air leakage, water levels in the evaporator shells, proper venting of the evaporator tube nests, scale or other deposits on the evaporator tubes, and draining of the evaporator tube nests.

A vacuum reduction resulting from any factor other than deposits on tube surfaces should be eliminated. This, in turn, will reduce deposits and greatly prolong the time intervals between cleanings.

Loss of vacuum resulting from deposits on evaporator tubes should be gradual. Under normal conditions, there will be no perceptible change in vacuum for any one day's operation. A sudden drop in vacuum should be traced to causes (listed above) other than scale deposits.

Air Leakage. Since the generating steam circuit operates under a vacuum ranging from 16 inches Hg to approximately

1 inch Hg (depending upon scale deposits), it may be subject to air leaks. Leaks from the steam side of the first-effect tube nest to the first-effect shell space will cause losses of capacity and economy. Air leaks from the atmosphere into the generating steam line (downstream from the orifice plate), the first-effect tube nest front header, and the first-effect tube nest drain piping (up to the drain pump discharge side) will cause a loss of vacuum and capacity. Air leaks in this part of the distilling plant may be less noticeable than air or water leaks elsewhere because the effect on the plant is similar to to the scaling of the tube surfaces.

A check for possible air leakage into the generating steam circuit can be readily made by means of the compound gage and the thermometer, which are installed on the steam head of the first-effect tube nest. The value of these two readings can be compared with the data found in the steam tables of the manufacturer's instruction book. The value of the vacuum should be in proportion to the amount of scale deposits on the surfaces of the first-effect tubes. If the amount of scaling is known, the value of the vacuum reading should indicate any possible air leakage. For example, with clean evaporator tubes the reading of the compound gage should show a value of 16 inches vacuum. Any reading considerably lower than this value will indicate air leaks in the generating steam circuit. In addition, the thermometer should read approximately 176° F. Any reading considerably higher than this value will indicate abnormal conditions.

Routine inspections and tests should be made to check for any possible air leaks in the distilling plant. Any air leaks found should be immediately corrected and precautionary measures should be taken to prevent additional air leaks from occurring.

Water Levels in Evaporator Shells. A reduced first-effect tube nest vacuum and capacity can result from too low a water level in any evaporator shell. On most plants, the water levels are controlled by hand regulation of the feed valves. Inability to feed the first-effect shell is usually due to scale deposits in the sea-water sides of the air ejector con-

denser and the vapor feed heater, or to obstructions in the feed line. Inability to feed subsequent effects is due to air leakage, or heavy scale deposits, in the feed lines between effects. It is important that the upper and lower gage glass fittings be free of scale, as plugging of these lines will result in false water level indications. Air leaks around the gage glass will also result in false levels in the gage glass.

Routine inspections and cleaning, as established by service needs, should be made for scale formation in the various component parts of the distilling plant. A check-off list, noting the last time each component part was cleaned or inspected for scale deposits, should be maintained. In this manner, preventive maintenance can be carried out with assurance that normal operation will not be affected by excessive formation of scale deposits in heat exchangers, piping, and fittings.

The pressure differential between the first-effect and the second-effect chambers permits the second-effect feed to be discharged into the second-effect shell. Air leaks have occurred between the first- and second-effect shells in the two-effect distilling plants. Large air leaks of this type can be readily detected when the vacuum gage for the first-effect space reads approximately the same as the vacuum gage for the second effect. In other words, both gages will indicate approximately 26 inches of vacuum. Large air leaks of this nature will disrupt the operation of the plant. The leaks must be located, by means of an air test, and repairs made.

Proper Venting of Evaporator Tube Nests. Improper venting of the evaporator tube nests causes either an accumulation of air in the tubes, with a loss of capacity, or an excessive loss of tube nest steam to the distilling condenser, with loss of economy. Troubles of this nature result mostly from poor operational procedures rather than from material failures.

Scale Deposits on Evaporator Tubes. During normal operating conditions, scale deposits will form on the evaporator tubes of the distilling plant at a certain rate. The rate of scaling depends upon the concentrations of suspended

matter and carbonate salts present in the sea or fresh water used to feed the distilling plant. However, the important point to remember is that excessive scaling of the evaporator tubes can be caused by improper operation of the distilling plant. As a supervisor, or trouble shooter, you should be able to recognize the difference between normal and abnormal rates of scale formation on the evaporator tubes.

Oil, mud, and vegetable matter leave an organic deposit, which is difficult to remove and interferes with the proper operation of the distilling plant. When the ship is passing through water where large amounts of oil or mud are present, the distilling plant should be secured temporarily until water conditions have cleared up. Precautionary measures should always be taken to ensure that the water is suitable for use as feed water in the distilling plant. Operation of the plant with shore-water feed should be kept to an absolute minimum because the use of some shore waters causes a tough adherent scale to form on the evaporator tubes.

Feed water treatment and chill-shocking should be considered when checking on the procedures used in operating a distilling plant. When proper methods are used, scale formation can be kept to a minimum, ensuring a maximum output of the distilling plant for a longer period of time. The authorized procedures for boiler compound—cornstarch feed water treatment and chill-shocking may be found in chapter 58 of BuShips *Manual*.

The output of the plant is not reduced appreciably by scale deposits on the evaporator tubes until the deposits have caused a reduction in the first-effect tube nest vacuum to 1 or 2 inches Hg. When the first-effect tube nest vacuum is lost entirely, the reduction in output becomes very great. Assuming the reduction in vacuum results from scale deposits and not from improper operating conditions, the evaporator tubes should be cleaned when the tube nest vacuum approaches zero. When the plant is operating properly and the evaporator feed water has been treated, the interval between cleaning periods should be at least 6 months.

As a supervisor, the MM1 or C should instruct lower-rated

personnel in the proper methods of removing scale from the evaporator tubes and from other parts of the distilling plant. Evaporator tubes should be scaled mechanically. Acid cleaning by ship's personnel is prohibited. However, when authorized by BuShips, naval shipyards may use a weak acid solution in cleaning the distilling plant.

The density of the brine discharged overboard should never exceed 1.5 thirty-seconds. The brine concentration is dependent mainly upon the quantity of brine pumped overboard and upon the amount of fresh water produced. If the brine concentration is too high, there will be an increase in the rate of scaling of the evaporator tubes, and the quality of the distillate may be impaired. If the brine concentration is too low, there will be a loss in capacity and economy, and it will be difficult to obtain proper feeding. Brine density must be maintained at the proper value to ensure trouble-free operation and maximum output of the distilling plant. If trouble is incurred in maintaining the proper brine density, a material inspection should be made of the brine pump and piping system to determine the cause of the trouble.

The brine piping should be kept reasonably clean and the amount of scale formation should be known at all times. Scale inside the piping is difficult to remove. Advantage should be taken of a naval shipyard repair period to have the brine lines cleaned out by chemical methods. The valves in the brine piping system should be maintained in a satisfactory operating condition to prevent any interference with the operation of the plant. The Macomb strainer, on the suction side of the brine pump, should be inspected and cleaned at routine intervals to prevent any excessive accumulation of scale that may result during abnormal operating conditions of the plant.

In accordance with service needs, routine inspections should be made of the brine pump to ensure that the pump is in a good material condition at all times. Wearing ring clearances should be measured and recorded. The pump impeller, housing, and associated piping should be inspected

for scaling and cleaned as necessary. Pump repairs should be made before any defective conditions become serious enough to cause unsatisfactory operation of the pump.

The brine pump gland packing should be inspected and renewed periodically. Since the pump suction operates under a vacuum, care should be taken to prevent air leaks. The packing gland should receive sufficient sealing water, and the lantern ring should be in its proper position. Operating personnel should be cautioned not to insert any additional packing into the pump gland, from time to time, but to completely renew the packing each time it becomes necessary to make corrections. To ensure that the brine pump is properly vented at all times, care should be taken to see that the vent line is free from scale deposits which may clog the line. In case the pump motor has been overhauled, precautions must be taken to see that the direction of rotation is correct for the pump. The pump motor should operate at its rated speed at all times.

Draining of Evaporator Tube Nests. Flooding of the gage glass on any tube nest drainer is a positive indication of poor drainage of that tube nest. However, the fact that a level is indicated in the gage glass is not necessarily an assurance of proper drainage, because air leaks at the gage glass fittings can result in a false liquid level indication. When a tube nest is properly drained, the temperature of the drains is within 10° to 15° F of the saturated steam temperature in the tube nest. It is particularly important to guard against poor drainage of evaporator tube nests. Poor drainage may result not only in a reduction in the first-effect tube nest vacuum (and consequently greater scale formation and need for more frequent cleaning), but also in a loss of condensate through the tube nest vent lines.

Adequate inspections should be made to ensure that the drain regulators are in a good material condition and that the units perform their functions properly. Since the drain lines, up to the discharge side of the pump, are under a vacuum, precautionary measures should be taken to prevent any possible air leaks.

To ensure proper operation of the tube nest drain pump, the correct preventive maintenance procedures should be followed. The tube nest drain pump and the brine pump are subject to similar troubles.

### Last-Effect Shell Vacuum

Schematic diagrams (such as figs. 10–1 and 10–2) in most manufacturers' instruction books indicate that a vacuum of approximately 26 inches Hg should be obtained in the last-effect shell when the initial temperature of the circulating water is 85° F, and that the vacuum should be higher when the circulating water is colder.

Failure to obtain a vacuum of 26 inches Hg, or more, should first be traced to one of the following factors: elimination of air leaks, proper operation of air ejectors, sufficient flow of circulating water, and effective use of heat transfer surface in the distilling condenser.

Air Leaks. The importance of the elimination of all air leaks cannot be overestimated. Most distilling plant troubles result directly from air leaks. Air leaks in the shells of a distilling plant cause a loss of vacuum and capacity. Extreme care should be taken in making up all joints and keeping them tight. All joints should be tested under pressure and shellacked frequently.

There are several methods in which tests can be made for air leakage of the tube nests, heat exchangers, shell, and associated piping systems of the distilling plant. When the plant is in operation, a candle flame or soapsuds can be used to test all joints and similar parts that are under vacuum. With the plant secured, air pressure tests can be used on the various component parts of the distilling plant. With the use of the manufacturer's instruction book, or blueprints, the different parts of the plant can be isolated and placed under an air test. In the same manner, air leakage may be detected by hydrostatically testing the various component parts of the plant. When performing air pressure or hydrostatic tests, precautions should be taken not to exceed the

maximum limit of the test pressures specified by the manufacturer's instruction book, or blueprints.

PROPER OPERATION OF AIR EJECTORS. Faulty air ejector operation is most frequently caused by insufficient steam pressure or wet steam at the air ejector nozzle. During the first few months of operation of a new plant, a clogged strainer or nozzle may also be responsible for faulty operation of the air ejectors.

If necessary, the air ejector nozzle throats can be cleaned by means of the special nozzle reamers furnished each ship for this purpose. Ordinary sharp-edged tools should not be used for cleaning nozzles (damage will be caused to the surface and the efficiency of the air ejectors will be impaired).

A procedure for testing air ejectors will usually be found in the manufacturer's instruction book. In general, the same maintenance procedures should be followed for air ejectors in distilling plants as for air ejectors in main condensers.

The steam pressure at the nozzle inlet must not be less than that for which the air ejector is designed. There may be a substantial pressure drop in the steam line and it may become necessary to carry a higher steam pressure. If necessary, the air ejector steam pressure may be increased as much as 10 to 15 psi.

SUFFICIENT FLOW OF CIRCULATING WATER. An insufficient flow of circulating water is indicated if the temperature rises more than 20° F in passing through the condensing section of the distilling condenser. The last-effect shell pressure is directly dependent upon the distilling condenser vacuum. This vacuum is dependent upon the temperature and quantity of the circulating water, and the proper operation of the air ejectors. Too low an overboard discharge temperature of the distiller condenser circulating water is accompanied by capacity and efficiency losses of the distilling plant. The overboard discharge temperature should be kept as high as possible, without exceeding the desired 20° F temperature rise through the distiller condenser. In addition, limiting the quantity of circulating water serves to prolong the service life of the condenser tubes and tube sheets.

When troubles occur which do not result from improper operating procedures, an inspection should be made of the condenser circulating water system to determine the cause of faulty operation.

Adequate preventive maintenance procedures should be carried out to ensure that the circuating water pump, as well as other distilling plant pumps, is maintained in good material condition. Although the circulating water pump does not operate under a vacuum, the maintenance and repair procedures for this pump are similar to those of the other pumps of the plant.

Routine procedures should be carried out for the inspection of the proper setting and maintenance of the back-pressure regulating valve. If this valve is not functioning properly, the valve parts should be replaced, and repairs to the valve made before its faulty operation interferes with the operation of the distilling plant.

To ensure that the condenser circulating water system is clean and free from scale and foreign material, the piping should be inspected and cleaned in accordance with service conditions. The operator of the distilling plant should be instructed to make periodic inspections and clean the strainer before any accumulated foreign matter interferes with the proper operation of the system.

EFFECTIVE USE OF HEAT TRANSFER SURFACE IN DISTILLING CONDENSER. Failure of the distilling plant to produce normal full-load output when the pressure above the orifice is 5 psi and the first-effect tube nest vacuum is several inches or more of mercury always indicates improper drainage of the condenser or of one of the evaporator tube nests subsequent to the first effect. Complete flooding of the flash chamber gage glass is also a positive indication of improper draining of the condenser. It should be kept in mind that air leaks at the gage glass fittings may result in a false water level.

A temperature difference of more than 5 to 10° F between the temperature of the last-effect shell and the temperature of the condensate at the condensate cooler inlet is another indication of improper drainage. The fact that this tem-

perature difference is in the proper range does not necessarily indicate proper drainage.

Scale deposits are unlikely to form inside distilling condenser tubes if the plant is properly operated and a full flow of circulating water is maintained. However, if scale deposits occur, the tubes should be cleaned.

Venting of the vapor side of the distilling condenser is continuously accomplished by the air ejectors. Venting of the salt-water side of the distilling condenser and other units need not be continuous. Precautionary measures should be taken to see that the operator of the plant uses proper procedures in venting the salt-water side of the condenser.

Proper operating and maintenance procedures should be carried out to ensure that the condensate pump is is good material condition at all times. Any malfunction of the condensate pump will be reflected in the improper performance of the condensate or fresh-water system of the distilling plant.

## CARE AND MAINTENANCE OF DISTILLING PLANTS

Proper operation is an important factor in maintaining a distilling plant in good condition, so that the maximum output can be obtained at all times. The MM1 or C in charge of a distilling plant should have a thorough knowledge of the proper operating procedures, in order to instruct and supervise the personnel who operate the plant. In addition, the MM1 or C should have a good knowledge of the required maintenance procedures, tests, and inspections, to ensure good material conditions and the correction of defects.

The required detailed information concerning the operation, inspections, tests, and repairs for a specific distilling plant can be obtained from the manufacturer's instruction book, blueprints, or chapter 58 of BuShips *Manual*.

### Trouble Shooting on a Distilling Plant

When troubles occur during the operation of a distilling plant, the MM1 or C in charge of the plant should be notified.

If the cause of the trouble is not known, steps should be taken to locate the cause, and to make the necessary corrections or repairs. In general, most distilling plant troubles can be located and corrected by properly trained operating personnel. In cases where troubles are of a difficult nature, such as low output, the MM1 or C should take an active part as a trouble shooter in inspecting and detecting the cause of the trouble.

When supervising the operation of a distilling plant, the MM1 or C should check the daily operating records. By checking the various temperature and pressure readings, he can detect any abnormal readings, and unsatisfactory material conditions can be corrected. In order to obtain reliable readings, the thermometers and gages must be maintained in good condition at all times. If proper precautionary procedures are not used, troubles may accumulate, or exist for a long time, until they finally cause malfunctioning and a possible shutdown of the plant for major repairs. The supervisor is also responsible for seeing that a good preventive maintenance program for the distilling plant is carried out.

When distilling plant troubles occur, the first step to take is to check the readings of the various thermometers and gages. These readings should be checked against the previous hourly reading entered in the operating record. As a rule, an erratic or abnormal reading will indicate trouble in one of the seven different circulating systems, or in a component part of the distilling plant. With the aid of the manufacturer's instruction book and drawings, all possible troubles that may occur in the isolated system, or part, and that will produce the same abnormal readings, should be noted. Each item on this list of probable troubles should then be checked by means of a detailed inspection. The items that involve the least amount of work, or dismantling, should be inspected first. This procedure of inspections and tests of individual units of a system, or the major parts of a distilling plant, should be continued until the cause of the trouble has been located.

There may be times when all component parts of a system under investigation will be in good condition. This may be confusing to inexperienced personnel. However, the trouble shooter should start again and recheck the probable causes of the trouble. With the additional knowledge gained from the inspections and tests that were made, the trouble shooter can reconsider the symptoms of the trouble. It is possible that troubles existing elsewhere in the system may cause similar results.

One of the most common troubles with distilling plants is a low output. In many cases, this type of trouble is the most difficult to locate because it depends upon various factors. In any attempt to locate the causes for low output, both the operational procedures and the material conditions must be carefully investigated. Low output may result either from an accumulation of troubles or from unsatisfactory conditions. In checking on the numerous possibilities which may cause a low output of the distilling plant, a systematic procedure should be followed. The investigation should not be stopped when one unsatisfactory condition is found, but continued until all possible troubles have been carefully checked. Continuous trouble with a low distilling plant output can usually be traced to inexperienced operating personnel and to inadequate preventive maintenance procedures.

### Distilling Plant Repairs

Under normal conditions, only a small amount of repair work will be necessary in maintaining a distilling plant in good operating condition. At least once every 6 months (preferably every 3 months), each pump should be dismantled and an inspection made of the wearing rings, impeller, shaft, and bearings. At the same time the pump should be completely repacked. Precautionary measures should be taken to inspect the various pumps in sufficient time so that defective conditions can be corrected before the operation of the pump is impaired. The full allowance of repair parts should be maintained on board at all times. Advantage should be taken of tender and naval shipyard repair

periods, to have repairs made which are considered beyond the capacity of the ship's force.

Valves and piping should be kept in good condition by means of inspections and tests, and by making necessary repairs. Salt-water valves, such as the back pressure valve, will require frequent inspections and more maintenance work than other valves. Where a distilling plant has been in operation for a number of years, new sections of salt-water lines may have to be manufactured by a repair activity. It is better, and more economical, to renew an entire pipeline instead of only one or two bad sections of that line.

In case of a leak in a heat exchanger, the defective tube(s) should be located by means of an air pressure or a hydrostatic test, in accordance with the recommended procedure in the manufacturer's instruction book. Blueprints should also be used to study the construction details of the individual heat exchanger. Since small leaks may be difficult to locate, tests should be carefully made (preferably by experienced personnel). As soon as a leaky tube has been located, it should be plugged at both ends. Special composition plugs, which are provided in the allowance of repair parts, should be used. The data regarding the number and location of plugged tubes should be entered on the Machinery History Card for the unit of the distilling plant.

Since plugging the tubes reduces the amount of heating surface, the heat exchanger will fail to give satisfactory performance after a number of tubes have been plugged. It will then become necessary to retube the heat exchanger. Under normal conditions, this work should be accomplished at a naval shipyard.

A complete record of the number of plugged tubes in a heat exchanger should be maintained, so that a repair item can be carried in the Current Ship's Maintenance Project (CSMP) for a retubing job at the next routine naval shipyard overhaul period.

Repairs of this nature should be made, whenever possible, by tenders or repair ships, or at advanced bases. However, repair parts and a number of special tools are included in

the ship's allowance list, so that emergency repairs can be made to the heat exchangers and other parts of the distilling plant.

A check-off list should be made for all zincs installed in the various parts of the distilling plant. This check-off list will help to ensure a proper maintenance procedure for the cleaning and replacement of zincs. Failure to replace the zincs properly may make major repairs necessary.

## SUMMARY

The MM1 and C must be familiar with the operation, maintenance, and repair of the types of distilling plants commonly used in the Navy.

You may be assigned as a supervisor in charge of a distilling plant; in this case, you must be able to instruct and supervise personnel in the proper operating procedures and in routine maintenance work. A good preventive maintenance program should be carried out to ensure trouble-free performance of the plant. When called upon, the MM1 or C should be capable of locating the cause of any major distilling plant trouble, and should perform or recommend the necessary repairs.

## QUIZ

1. A 30,000 gpd installation is classified as what type of distilling plant?
2. Who is responsible for locating the trouble and making the necessary repairs to the distilling plant?
3. If the normal amount of steam at the proper pressure is not supplied to the plant, what trouble results?
4. What first-effect tube nest pressure range should be maintained within a distilling plant?
5. Why should the vacuum inside the first-effect tubes be as high as possible?
6. What 5 primary factors affect the first-effect tube nest vacuum?
7. What kind of losses will be caused by air leaks from the steam side of the first-effect tube nest to the first-effect shell space?
8. A check for possible air leakage into the generating steam circuit can be readily made by what means?

9. What causes an accumulation of air in the evaporator tubes or an excessive loss of tube nest steam to the distilling condenser?
10. What effect will scale deposits have on the evaporator tubes when the vacuum aproaches zero?
11. If a reduction in vacuum has resulted from scale deposits and not from improper operating conditions, when should the evaporator tubes be cleaned?
12. What is the maximum allowable density of the brine discharged overboard?
13. What is a positive indication of poor drainage of an evaporator tube nest?
14. Most of the operating troubles of a low-pressure plant can be traced directly to what source?
15. What are the most common causes of air ejector troubles?
16. Air ejector nozzle throats are cleaned, when necessary, by what means?
17. The last-effect shell pressure is directly dependent upon what factor?
18. When are scale deposits inside distilling condenser tubes unlikely to occur?
19. Who is generally responsible for checking the daily operating records of a distilling plant?
20. When distilling plant troubles occur, what step should be taken first?
21. In attempting to locate the causes for a low output, what must be carefully investigated?
22. How often should the wearing rings of pumps be inspected?
23. If there is a leak in a heat exchanger, how may the defective tubes be located?
24. Under normal conditions, the retubing of a heat exchanger should be accomplished by what personnel?

CHAPTER 11

# REFRIGERATION MAINTENANCE AND REPAIR

On Navy vessels the proper operation, maintenance, trouble shooting, and repair of refrigeration systems are major responsibilities of First Class or Chief Machinist's Mates.

This chapter deals with the maintenance of a Freon–12 system, giving special emphasis to compressors, condensers, expansion valves, switches, and trouble shooting.

## MAINTENANCE OF THE FREON–12 SYSTEM

### Checking the System

To ensure proper care and operation of the refrigeration system, it is necessary to make systematic tests, inspections, and checks. It is good engineering practice to make an hourly check of all temperatures and pressures throughout the system and of the oil level in the compressor crankcase.

One of the best methods for checking plant operation is to compare the temperatures and pressures of the plant with corresponding temperatures and pressures which were recorded during a period when the plant was known to be operating properly. The accuracy of the comparison will depend on the similarity between conditions existing when each set of readings was taken.

A daily operating log for refrigeration equipment should be maintained and used as a guide for a continuing analysis of the operating conditions found in a refrigeration plant. A typical log is shown in figure 11–1. "Machine room temperature," "water supply," and "weather" are influencing

COMPRESSOR NO. 2

DATE 2 Feb 1953

| TIME | MACH. ROOM TEMP | COMPR SPEED R.P.M. OR % | COMPRESSOR: F-12 SUCTION LBS. GAGE | F-12 SUCTION TEMP. °F | F-12 DISCHARGE LBS. GAGE | F-12 DISCHARGE TEMP °F | OIL LBS GAGE | OIL BULLSEYE LEVEL | CRANKCASE RELATIVE TEMP. | CRANKCASE NOISE | CONDENSER: WATER SUPPLY LBS. GAGE | WATER SUPPLY TEMP. °F | WATER O'V'B'D. TEMP. °F | F-12 LIQUID TEMP °F | CONDITION AT SIGHT FLOW | WEATHER: DRY B. TEMP. °F | WET B. TEMP. °F | REFRIGERATED SPACES: ICE SET TEMP. °F | COMPARTMENT TEMPERATURE °F: Meat RM. #1 | Thaw RM. | Veg. RM. | Dairy RM. | RM. | RM. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0100 | 88 | 540 | 7 | 38 | 95 | 162 | 27 | OK | warm | OK | 24 | 60 | 80 | 82 | OK | 82 | 73 | 7 | 17 | 40 | 37 | 32 | | |
| 0200 | 89 | 540 | 4 | 46 | 95 | 162 | 25 | OK | warm | OK | 24 | 60 | 82 | 82 | OK | 82 | 73 | 9 | 15 | 38 | 40 | 32 | | |
| 0300 | 89 | 540 | 2 | 56 | 95 | 194 | 22 | OK | warm | OK | 24 | 58 | 80 | 86 | vapor bubbles | 80 | 72 | 11 | 19 | 42 | 42 | 36 | | |
| 0400 | 88. | 540 | 3 | -4 | 85 | 143 | 24 | low | cold | knocks | 24 | 58 | 80 | 76 | OK | 80 | 70 | 10 | 14 | 40 | 40 | 34 | | |
| 0500 | 88 | 540 | 12 | 35 | 95 | 153 | 32 | low | warm | OK | 24 | 60 | 80 | 81 | OK | 80 | 69 | 9 | 15 | 40 | 39 | 32 | | |
| 0600 | [illegible] | 540 | 12 | 36 | 96 | 174 | 32 | OK | warm | OK | [illegible] | 58 | 82 | [illegible] | | | | | | | [illegible] | [illegible] | | |
| 2000 | 94 | 540 | 8 | 29 | 106 | 168 | 28 | OK | warm | OK | 24 | 58 | 90 | 92 | OK | 86 | 71 | 7 | 18 | 41 | 40 | 31 | | |
| 2100 | 93 | 540 | 10 | 31 | 107 | 165 | 30 | OK | warm | OK | 24 | 58 | 90 | 90 | OK | 84 | 72.5 | 9 | 22 | 42 | 39 | 32 | | |
| 2200 | 93 | 540 | 10 | 30 | 106 | 162 | 31 | OK | warm | OK | 24 | 58 | 90 | 91 | OK | 84 | 70 | 11 | 23 | 41 | 41 | 33 | | |
| 2300 | 93 | 540 | 7 | 30 | 120 | 168 | 28 | OK | warm | OK | 24 | 58 | 90 | 93 | OK | 84 | 72.5 | 10 | 18 | 40 | 39 | 32 | | |
| 2400 | 93 | 540 | 6 | 30 | 115 | 152 | 26 | OK | warm | OK | 24 | 58 | 90 | 92 | OK | 84 | 71 | 7 | 16 | 39 | 38 | 31 | | |

REMARKS: 0300 – Refrigerant shortage – checked and corrected leaky flange at suction line connection to compressor – added 30 lbs Freon-12

0400 – Expansion valve on #2 coil Meat Room #1 froze in open position. Flooding refrigerant to compressor – defrosted valve and connected dehydrator into system.

2000 – 3/8" frost on Meat Room #1 coils – Started defrosting.

2200 – Completed defrosting.

**Figure 11–1.—Typical daily operating log for refrigeration equipment.**

conditions, and a record of them is desirable for comparative results. Where variable speed compressor operation is possible for a proper interpretation of results, "compressor speed" must be recorded. Other column heads represent operating results.

An inspection should be conducted, at least monthly, for testing belt tension and refrigerant leakage. At the same time, refrigerator door gaskets, coils, and control contacts should be inspected and condensers checked for cleanliness.

The ice cream units, refrigerators, drinking water coolers, etc., should be inspected daily.

## Charging the System

Information concerning the charging of Freon–12 systems may be found in chapter 59, section 118, of BuShips *Manual*. The amount of Freon–12 charge must be sufficient to maintain a liquid seal between the condensing and evaporating sides. When the low-pressure switch stops the compressor, the liquid receiver of a properly charged system is generally about 85 percent full of Freon–12. Freon–12 charge necessary for an individual plant is usually stated in the plant instruction book or on the ship's drawings.

The system must not be recharged until all leaks are found and completely repaired. Immediately following, or during, the process of charging, the system should be carefully checked for leaks.

Remember that a refrigeration system should have an adequate charge of refrigerant at all times; otherwise its efficiency and capacity will be impaired.

## Opening a Charged System

Whenever it becomes necessary to open a fully charged system for repair purposes, the final evacuation should be to a pressure slightly above atmospheric pressure (1 to 2 psi gage), to prevent air from entering the system. If the gage reading drops to zero, or below, sufficient refrigerant should be admitted to the evacuated part to raise the pressure to

between 1 and 2 psi gage. Connections may then be broken and the necessary repairs made. If more than a few minutes must elapse after the connections are broken, the open ends of the system should be plugged.

When reconnecting the evacuated part to the system, make one joint first and blow out the part under investigation, with gas from the system, then quickly finish making up the other joint.

### Purging Air From the System

Operate the system for 30 minutes. Observe the pressure and temperature as indicated on the high-pressure Freon gage. Read the thermometer in the liquid line, and compare it with the temperature conversion figures shown on the discharge pressure gage. If the temperature of the liquid leaving the receiver is more than 15° F lower than the temperature corresponding to the discharge pressure, the system should be purged. While the system is still operating, slightly open the purge valve on the condenser. Purge very slowly, at intervals, until the air is expelled from the system and the temperature difference drops below 15° F.

### Moisture Precautions

Preventing the entrance of air into the refrigeration system eliminates the necessity of purging the condenser; but it is also very important to prevent moisture from entering the system. Moisture can mix with oil to form a sludge that will prevent automatic controls from functioning; it can condense and freeze at the orifices of the thermal expansion valves and cause the valves to stick open; it may cause the bellows to become brittle under cyclic stress; and it may cause corrosion of the internal surfaces of the system.

### Testing for Leaks

During the regular monthly inspection of refrigerating equipment, the system should be checked for leakage of refrigerant. However, you should always be on watch for abnormal log readings or unusual operating conditions which

would indicate a shortage of refrigerant; such an indication necessitates testing the entire system for leaks. The following are symptoms of shortage of refrigerant or leaks:

1. High suction line temperatures.
2. Crankcase and cylinder temperatures relatively high, with low suction pressure.
3. Liquid line refrigerant temperature too high.
4. Bubbles in the refrigerant sight flow indicator.
5. Liquid refrigerant carrying partially through the coil, with considerable superheat at thermal element location.
6. Compressor running continuously.
7. Excessive oil seepage at shaft seal connection.
8. Oil seepage at refrigerant system piping and compressor connections.

There are two methods of testing a refrigerating system for leaks—the halide torch method and the soapsuds method. Your choice of method will depend, among other things, upon the size of the leak and the ventilation of the space. A halide torch should NEVER be used in magazines.

HALIDE TORCH. The most positive method of detecting leaks in Freon–12 systems is by use of the halide torch (fig. 11–2). Atmosphere suspected of containing Freon–12 vapor is drawn by injector action through an exploring hose into the torch burner. The air passes over the copper reactor plate, which is heated to incandescence. If there is a minute trace of Freon–12 present, the torch flame will change from its normal blue, or neutral color, to a characteristic green color as it comes in contact with the reactor plate. The shade of green will depend upon the relative amount of Freon–12 present, being pale for small concentrations and dark for heavier concentrations. Excessive quantities of Freon–12 color the flame a vivid purple, and may even extinguish it by driving out the supply of oxygen in the air.

Of the several types of halide torches available, most employ acetylene gas or alcohol as a fuel. The prest-o-lite-torch has been found to be satisfactory for the detection of Freon–12 leaks. If a pump pressure type of alcohol-burning torch is used, care must be taken that the air pumped into

the tank is pure. To obtain good results in using the halide leak detector, the following precautions must be observed:

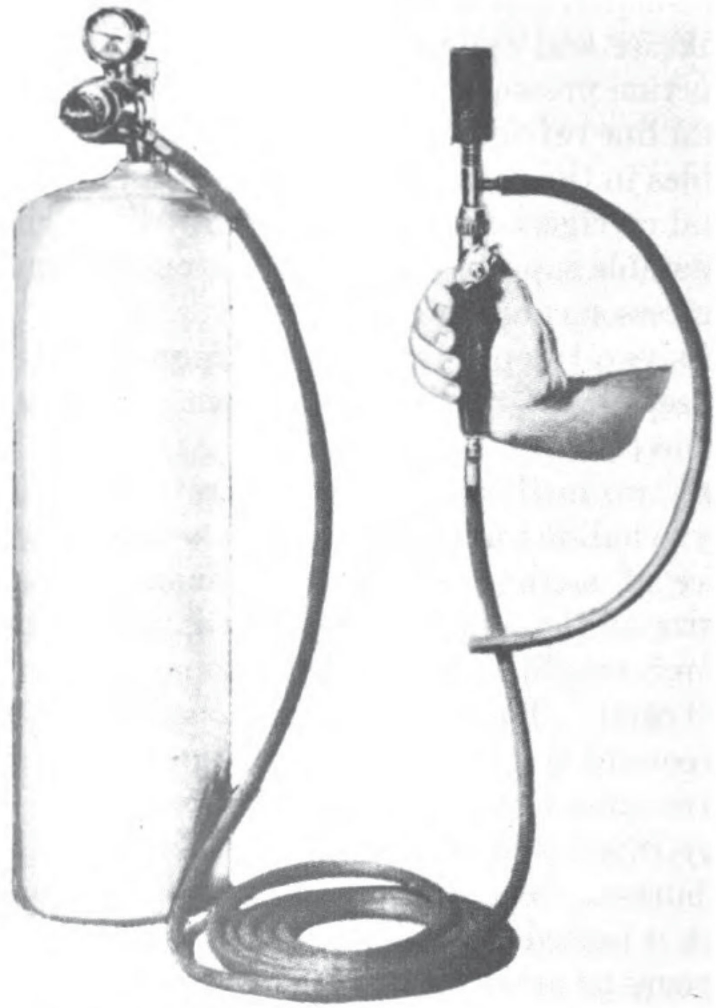


**Figure 11–2.—Prest-O-Lite halide leak detector.**

1. Be sure that the reactor plate is in place.
2. Adjust the flame low enough so that it does not extend appreciably beyond the end of the burner. (A small flame is much more sensitive than a large flame. If difficulty is experienced in lighting the torch when adjusted to produce the necessary small flame, block the end of the exploring hose until the flame ignites, then gradually open. However, DON'T use the torch if the atmosphere is heavily contaminated with Freon–12.)

3. If the flame persists in burning with a white or yellow color, the exploring tube is partially blocked with dirt and should be cleaned out.

4. Check to see that air is being drawn; this can be done by holding the end of the tube to the ear from time to time.

5. Hold the exploring tube close to the joint being tested, to prevent dilution of the sample by stray air currents.

6. Move the end of the exploring hose slowly and completely around each joint. Leak testing cannot safely be hurried. There is a definite time lag between the moment when air enters the exploring hose and the moment it reaches the reactor plate.

7. If a greenish flame is noted at any time, repeat the test in the same vicinity until the source of the Freon–12 is determined. If necessary, use soap bubbles to find the exact point at which a leak is occurring.

8. After a system has been operated, the lubricating oil circulates with the refrigerant in the system and where a leak exists, the oil usually collects on the exterior of the piping joints, etc., indicating the approximate location of system leaks. This oil must be carefully removed before the halide detector is used to determine the exact location of the leakage.

9. Always follow a definite procedure in testing for leaks, so that no joints will be missed. Be sure that you locate every leak; even a very small leak is not to be considered negligible. The extra time spent in testing all threaded, flared, soldered, welded, and valve cap gasket joints will be justified.

10. The system must never be recharged until all leaks are discovered and definitely repaired. Upon locating one leak, retest the system for other possible leaks.

Soapsuds. A halide torch is so sensitive that it is useless if the atmosphere is contaminated by excessive leakage of Freon–12. This is most likely to happen in a small or poorly ventilated compartment. In such a case, the soapsuds test must be used.

Prepare the soap-and-water solution so that it has the consistency of liquid hand soap, and will work up a lather on a

brush. The lather will remain wet for a longer period if a few drops of glycerin are added to the solution.

Apply the lather all the way around the joint, and then look carefully for bubbles. If a joint is so located that a part of it is not visible, use a small mirror to inspect it. Remember that it sometimes takes as long as a minute or more for bubbles to appear, if the leak is small. Doubtful spots should be lathered and examined a second time.

### Pressure Testing for Tightness

Pressure testing for tightness is generally performed for new installations by refrigeration repair personnel at naval shipyards or aboard repair ships. When such testing is indicated, refer to chapter 59 of BuShips *Manual* for the proper procedures.

### Dehydration and Evacuation of the System

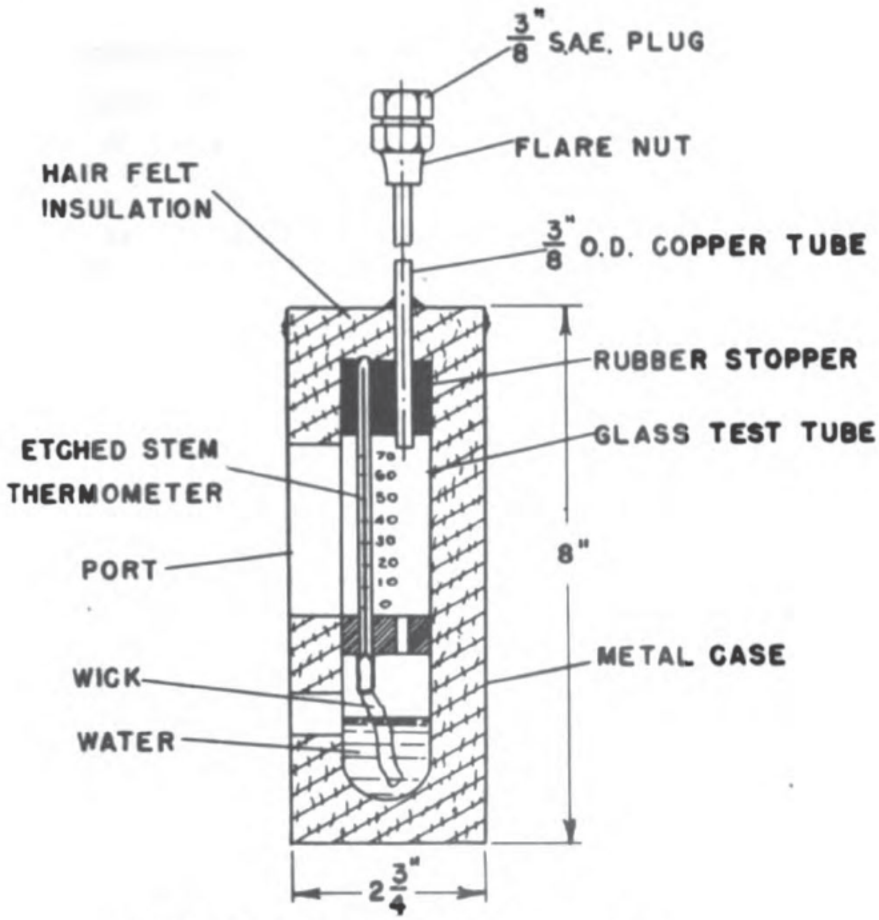
Where moisture accumulation must be corrected, the system should first be cleared of refrigerant and air. The time required for these processes will depend upon the size of the system and the amount of moisture present. It is good engineering practice to circulate heated air through the dehydrator and system for several hours, or as long as the dehydrator drying agent remains effective, before proceeding with the evacuation process. If possible, the dehydrated air should be heated to about 240° F.

Large dehydrators, suitable for preliminary dehydration of Freon–12 systems, are usually available at naval shipyards, and aboard tenders and repair ships.

After the preliminary dehydration, remaining moisture is evacuated by means of a two-stage high-efficiency vacuum pump having a vacuum indicator. (These vacuum pumps are available aboard tender and repair ships.)

The vaccum indicator shown in figure 11–3 consists of an insulated test tube containing a wet bulb thermometer with its wick immersed in distilled water. The indicator, or a mercury column, is connected in the vacuum pump suction

line. The suction line from the vacuum pump is connected to the Freon–12 charging connection in the refrigeration system. The refrigerant circuit should be closed to the atmosphere and the charging connection opened to the vacuum pump.




CONVERSION TEMPERATURE °F TO ABSOLUTE PRESSURE INCHES MERCURY

| TEMP. °F | ABS. PRESSURE INCHES MERCURY |
|---|---|
| 60 | 0.521 |
| 55 | 0.436 |
| 50 | 0.362 |
| 45 | 0.300 |
| 40 | 0.248 |
| 35 | 0.204 |
| 32 | 0.181 |

Figure 11–3.—Dehydrator vacuum indicator.

A two-stage pump is started for operation in PARALLEL so that maximum displacement may be secured during the initial pump-down stages. When the indicator shows a temperature of about 55° F (0.43 inch Hg, absolute), the pumps are placed in SERIES operation (wherein the discharge from the first step enters the suction of the second step pump). The dehydration process will be reflected in the temperature drop of the vacuum indicator, as shown in figure 11–4. Readings will initially reflect ambient temperatures, then show rapidly falling temperatures until the water in the system starts to boil.

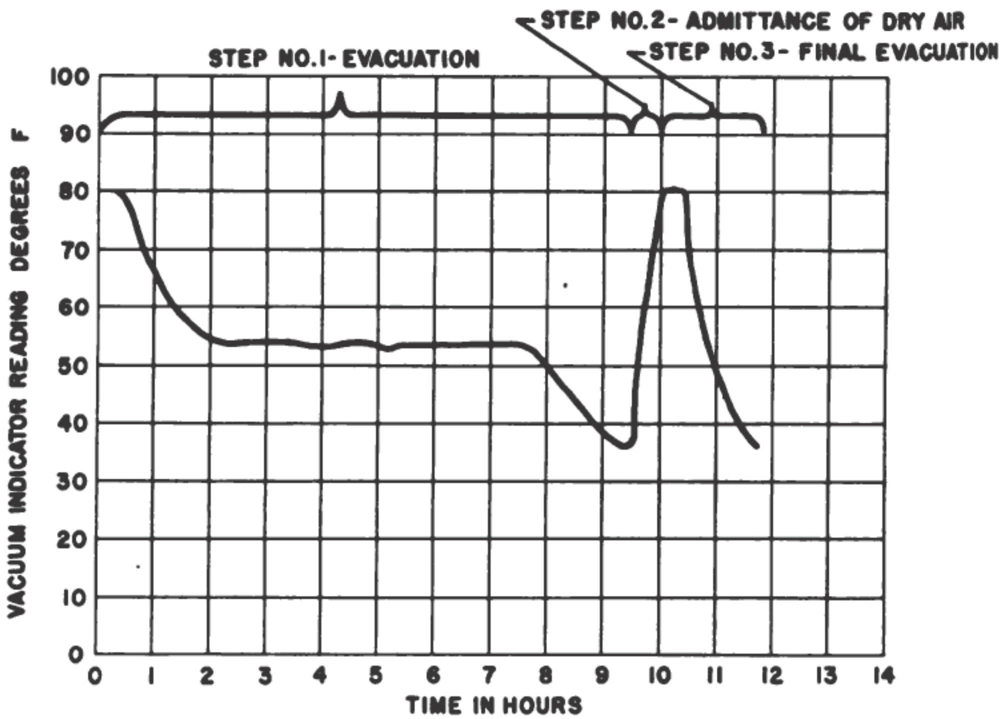



Figure 11–4.—Vacuum indicator readings plotted during dehydration.

When most of the evaporated moisture has been evacuated from the system, the indicator will show a decrease in temperature. When the temperature reaches 35° F (0.2 inch Hg, absolute), open the system at a point farthest from the pump; at this point, air should be drawn into the system through a chemical dehydrator, and meanwhile the pump should be operated to permit dilution of moisture present in the system. Close off the opening and re-evacuate until the indicator again shows a temperature of 35° F. At this point the de-

hydration process is complete; close the charging valve and then stop the pump.

Sometimes it will be impossible to obtain a temperature as low as 35° F in the vacuum indicator; the probable reasons for such a failure, and the corrective procedures to take, are as follows:

1. Presence of excess moisture in the system. The dehydration procedure should be conducted for longer periods.
2. Presence of absorbed refrigerant in the lubricating oil contained in the compressor crankcase. Remove the lubricating oil from the crankcase before proceeding with the dehydration process.
3. Leakage of air into the system. The leak must be found and stopped. It will be necessary to repeat the procedure required for detecting leaks in the system.
4. Inefficient vacuum pump or defective vacuum indicator. The defective unit(s) should be repaired or replaced.

## Reactivation of Dehydrator Drying Agent

Immediately after each period of use, or after the system has been opened for repairs, the drying agent in the dehydrator should be reactivated to remove traces of moisture introduced with the lubricating oil or refrigerant. This procedure is necessary to protect the drying agent (which would disintegrate if it should remain saturated with water), and to assure that the dehydrator will always be ready for use when required.

Reactivation is accomplished by removing the drying agent and heating it, for several hours, to a temperature of 250° to 300° F to bake out the moisture. The drying agent may be placed in an oven, or a stream of hot air may be circulated through the cartridge. These methods are satisfactory for reactivating commonly used dehydrating agents such as activated alumina, calcium sulfate, and silica gel. Where special drying agents are employed, they should be reactivated in accordance with specific instructions furnished in the instruction booklets. After reactivation, the drying

agent should be replaced in the dehydrator shell and sealed as quickly as possible, in order to prevent absorption of atmospheric moisture. When the drying agent becomes badly fouled or saturated with lubricating oil, it must be replaced by a fresh spare charge, or dehydrator cartridge, taken from a sealed container.

Remember that the dehydrators permanently installed in Freon–12 systems for naval vessels are designed to remove only the minute quantities of moisture unavoidably introduced into the system. Extreme care must be taken to prevent moisture, or moisture-laden air, from entering the system.

### Cleaning of Systems

Systems may accumulate dirt and scale as a result of improper techniques used during repair or installation. If such dirt is excessive and a tank-type cleaner is available, connect the cleaner to the compressor suction strainer. Where such a cleaner is not available, a hard wool felt filter, about 5/16-inch thick, should be inserted in the suction strainer screen. The plant should be operated with an operator in attendance, for at least 36 hours or until cleaned, depending upon the size and condition of the system.

## COMPRESSORS

### V-Belt Drive

Belts must be properly tightened. Excessive looseness will cause slippage, rapid wear, and deterioration of V-belts. On the other hand, a belt that is too tight will result in excessive wear of both the belt and main bearing of the compressor. In extreme cases it may cause a bad seal leak. If a belt is properly tightened, it should be possible to depress it, by the pressure of one finger, as much as 1/2 to 3/4 inch, at a point midway between the flyweel and motor pulleys.

When replacement of one belt of a multiple V-belt drive is necessary, a complete new set of matched belts should be installed. Belts stretch considerably during the first few hours of operation. Replacement of a single belt will upset

the load balance between the new and old belts and be a potential source of trouble. It is better practice to run the unit temporarily with a defective belt removed than to attempt to operate a new belt in conjunction with two or more seasoned belts.

V-belts, motor pulleys, and compressor flywheels should be kept dry and free of oil. Belt dressing should never be used.

## Checking Compressor Oil

If the apparent oil level observed immediately after a prolonged shut-down period is lower than normal, it is almost certain that the actual working oil level is far too low. After a sufficient quantity of oil has been added to raise the apparent oil level to the center of the bull's-eye sight glass, on the side of the compressor, the actual oil level should be checked as follows:

1. Operate the compressor on manual control for at least one hour. Then slowly close the suction line stop valve. If the compressor is operating on a water cooler or other coil which is apt to freeze, observe the temperature and interrupt compressor operation as necessary to prevent freezing. Repeat cycling until the total running time (one hour) is obtained.

2. Stop the compressor, turn the flywheel until the crankshaft and connecting rod ends are immersed in the lubricating oil, and immediately observe the oil level in the sight glass.

To check the oil level when the compressor has been running on its normal cycle, with no abnormal shut-down, proceed as follows:

1. Wait until the end of a period of operation; if the operation is continuous, wait until the compressor has been in operation at least ½ hour.

2. As soon as the compressor stops, turn the flywheel until the crankshaft and connecting rod ends are immersed in the lubricating oil, and observe the oil level in the sight glass.

Do not remove oil from the crankcase because of an apparent high level unless it is known that too much oil has been previously added, or unless it is apparent that oil from the crankcase of one compressor of the plant has been inadvertently deposited in the crankcase of another.

However, if the oil level is lower than its recommended height on the glass, additional oil should be added. Do not add more oil than is necessary to obtain the desired level. Too much oil can result in excessive oil transfer to the cooling coils.

ADDING OIL. There are two common methods of adding oil to a compressor. In one type of installation a small oil-charging pump is furnished for adding oil to the compressor crankcase. In another type, oil is placed in the compressor by means of a clean, well-dried funnel. In either case, care must be taken to prevent the entrance of air or foreign matter into the compressor.

When performing hourly checks of the compressors, you may observe no oil in the crankcase, or a very low oil level on the sight glass. This indicates that the oil has left the compressor and is circulating in the system, and it will be necessary to add oil to the normal level and operate the system. After the compressor has reclaimed the excessive oil in the system, the excess oil should be drained.

REMOVING OIL. To remove oil from the compressor crankcase, reduce the pressure in the crankcase to approximately 1 psi by gradually closing the suction line stop valve. Then stop the compressor, close the suction and discharge line valves, LOOSEN the lubricating oil drain plug near the bottom of the compressor crankcase, and allow the required amount of oil to drain out. Since the compressor crankcase is under a slight pressure, do not fully remove the drain plug from the compressor, but allow the oil to seep out around the threads of the loosened plug. When the desired amount of oil has been removed, tighten the drain plug, open the suction and discharge line valves, and start the compressor. If an oil drain valve is provided in lieu of a plug, the required

amount of oil may be drained without the necessity of pumping down the compressor.

RENEWING LUBRICATING OIL CHARGE. When clean copper tubing is employed for the Freon–12 mains and evaporators, and reasonable care has been taken to prevent the entrance of foreign matter during installation, the oil in the compressor crankcase will probably not become sufficiently contaminated to require renewal. When iron or steel pipe and fittings are used in the Freon–12 system, a sample of oil from the compressor crankcase should be withdrawn into a clean glass vessel every three months. If the sample shows contamination, the entire lubricating oil charge should be renewed. It is good practice to check the cleanliness of the lubricating oil after each cleaning of the compressor suction scale trap.

### Testing Compressor Internal Discharge and Suction Valves

A Freon–12 compressor should NOT BE OPENED for valve inspection or replacement until it has been definitely determined that the faulty operation of the system is due to the improper functioning of the valves. Faulty compressor valves may be indicated by a gradual or by a sudden decrease in the normal compressor capacity. Either the compressor will fail to pump at all, or else the suction pressure cannot be pumped down to the designed valve, and the compressor will run for abnormally long intervals or even continuously. If the compressor shuts down for short periods, the compressor valves may be leaking.

If the refrigeration plant is not operating satisfactorily, it will be best to first shift the compressors and then check the operation of the plant. If the operation of the plant is satisfactory when the compressors have been shifted, this indicates that the trouble was with the compressor. However, if faulty operation of the plant is still indicated after the compressors have been shifted, the trouble is in the system, and not in the compressor.

The compressor discharge valves may be tested by pumping down the compressor to 2 psi gage, and then stopping the

compressor and quickly closing the suction and discharge line valves. If the discharge pressure drops at a rate in excess of 3 pounds in a minute and the crankcase suction pressure rises, there is evidence of compressor discharge valve leakage. If it is necessary to remove the discharge valves with the compressor pumped down, open the connection to the discharge pressure gage in order to release discharge pressure on the head. Then remove the compressor top head and discharge valve plate, being careful not to damage the gaskets.

If the discharge valves are defective, the entire discharge valve assembly should be replaced. Any attempt to repair them would probably involve relapping, and would require highly specialized equipment. Except in an emergency, such repair should never be undertaken aboard ship.

The compressor internal suction valves may be checked for leakage as follows:

1. Start the compressor by using the manual control switch on the motor controller.

2. Close the suction line stop valve gradually, to prevent violent foaming of the compressor crankcase lubricating oil charge.

3. With this stop valve closed, pump a vacuum of approximately 20 inches Hg. If this vacuum can be readily obtained, the compressor suction valves are satisfactory.

Do not expect the vacuum to be maintained after the compressor stops, because the Freon–12 is being released from the crankcase oil. Do not attempt to check compressor suction valve efficiency of new Freon–12 units until after the compressor has been in operation for a minimum of three days. It may be necessary for the valves to wear in.

However, if any of the compressor suction valves are defective, the compressor should be pumped down, opened, and the valves inspected. Defective valve(s) or pistons should be replaced with spare assemblies.

## Repair of Compressors

If the compressor is damaged to such an extent that it cannot be operated, it will be necessary, before opening the unit

for repairs, to close the suction and discharge stop valves and permit the refrigerant in the compressor to escape to the atmosphere through gage lines or purge valves.

Before opening an operating compressor for examination or repair, it is necessary to pump down the system. To pump Freon–12 out of the compressor, proceed as follows:

1. Close the suction stop valve.
2. Make certain that the compressor discharge valve is open.
3. Start the compressor and let it run on manual control until a slight vacuum is obtained.
4. Stop the compressor and immediately close the discharge stop valve. If the pressure indicated by the suction gage rises rapidly to 15 psi, or more, above zero pressure, there is still a considerable amount of Freon–12 in the crankcase. In this case, start the compressor with the manual control switch, and gradually close the suction valve. When the valve is completely closed, let the compressor run until the maximum vacuum is obtained.
5. After the vacuum is pumped, wait until the pressure builds up to 2 or 3 pounds above zero pressure before opening any part of the compressor or its connections.
6. Before proceeding with any work on the compressor, see that the switch is open, and fuses removed.

DISASSEMBLY. Before dismantling a compressor, make certain that the faulty operation of the installation is not caused by trouble in some other part of the system. Dismantle only the part of the compressor necessary to correct the fault.

Never open any part of the compressor unless the gage indicates a positive pressure inside the system. Unless this precaution is taken, moisture-laden air may enter the system.

As soon as internal machined parts (valves, pistons, shaft seal, crankcase) are removed, wrap them in clean paper to protect them from corrosion or other damage.

When disassembling the compressor, be careful not to injure the gaskets. When reassembling, use gaskets of identical thickness and material—the thickness determines the

clearance between the top of the compressor pistons and the discharge valve plate.

Compressor parts should be carefully marked when disassembled so that each part removed will be replaced in its original position when reassembled.

To disassemble or reassemble the compressor, use only the tools specified for the particular operation involved.

Reassembly. Before a compressor is reassembled, all parts—including replacement parts—should be carefully washed in carbon tetrachloride and permitted to dry in air. The final rinse should be made with clean carbon tetrachloride. Using chamois or hard, lint-free cloth facilitates cleaning. Care should be taken to prevent dirt, lint, water, or other foreign matter from entering the compressor during reassembly.

Replacement of Parts. Where necessary to remove, replace, or repair internal parts of the compressor, the manufacturer's instruction book should be consulted. The following precautions should be observed:

1. Carefully disassemble and remove parts, noting the correct relative position so that errors will not be made upon reassembly.
2. Inspect all parts that have been made accessible by removal of the parts requiring repair or replacement.
3. Make certain that all parts and surfaces are free of dirt and moisture.
4. Apply compressor oil freely to all bearing and rubbing surfaces of parts being reinstalled.
5. Place the pistons on the proper rods, facing in the same direction as they did originally.
6. If the compressor is splash-lubricated, see that the oil dipper on the lower connecting rod bearing is in correct position for dipping up oil when the machine operates.
7. Position the ends of the piston rings so that alternate joints come on opposite sides of the piston.
8. Remove the oil; clean the gasket surfaces and replace old gaskets with new ones.
9. Clean the crankcase and provide a fresh charge of oil.

## Evacuation of Air After Repair

Whenever repairs to a compressor are of such a nature that any appreciable quantity of air enters the unit during repairs, the compressor should be evacuated, after reassembly is completed, as follows:

1. Open wide to the atmosphere a discharge pressure gage line, or other connection in the compressor discharge line, ahead of the discharge line stop valves.
2. Start the compressor and let it run until the greatest possible vacuum is obtained.
3. Stop the compressor and immediately open the suction stop valve slightly in order to blow Freon–12 through the compressor valves and purge the air above the discharge valves through the open gage line. Then close the discharge gage line and open the discharge line stop valve. Remove all oil from the exterior of the compressor, particularly the joints, and test all compressor joints for leakage, using the halide leak detector.

## CONDENSERS

The compressor discharge line terminates at the refrigerant condenser. In shipboard Freon–12 installations, these condensers are usually of the multipass shell-and-tube type, with water circulating through the tubes. The tubes are expanded into grooved holes in the tube sheet so as to make an absolutely tight joint between the shell and the circulating water. Refrigerant vapor is admitted to the shell, and condenses on the outer surfaces of the tubes.

Any air which may accidentally enter the refrigeration system will be drawn through the piping and eventually discharged into the condenser with the Freon–12 gas. The air accumulated in the condenser is lighter than the refrigerant gas and will rise to the top of the condenser when the plant is shut down. A purge valve, for purging accumulated air from the refrigeration system when necessary, is installed at the top of the condenser, or at a high point in the compressor discharge line.

## Checking the Water-Cooled Condenser for Performance

An over-all check for water-cooled condenser performance may be used after, AND ONLY AFTER, the condenser has been properly purged. After the condition of the condensing surface has been determined, make preliminary preparations to the system as outlined in the procedure, discussed earlier in the chapter, used to check for noncondensable gases. Then proceed as follows:

1. Record the condensing temperature which corresponds to the pressure in the condenser, while the compressor is in operation.
2. Record the temperature of the water leaving the condenser.
3. Subtract the temperature of the water leaving the condenser from the condensing temperature obtained in (1). The temperature of the water leaving the condenser will be several degrees below the condensing temperature of pure Freon–12.
4. Clean the water side of the condenser, if the difference between the temperature of the outlet circulating water and the temperature corresponding to the condensing pressure increases 5° to 10° F above the temperature difference obtained when the condenser was in good condition and operating under similar heat loads, and if this difference is not caused by an overcharge of refrigerant or noncondensable gases.

## Cleaning of Condenser Tubes

In order to clean the condenser tubes properly, it is necessary first to drain the cooling water from the condenser and then to remove the water connections and water chests. When the water chests are removed, be careful not to damage the gaskets between the tube sheet and the water side of the water chest. Tubes should be inspected as often as practicable and be cleaned as necessary by the use of an approved method for cleaning steam condenser tubes, as stated in chapter 46 of BuShips *Manual.* Rubber plugs and an air or

water lance should be employed when necessary to remove foreign deposits. It is essential that the tube surfaces be kept clear of particles of foreign matter; however, care must be taken not to destroy the thin protective coating of corrosion products on the inner surfaces of the tubes. If the tubes become badly corroded, they should be replaced in order to avoid the possibility of losing the Freon–12 charge and admitting salt water to the Freon–12 system.

### Cleaning Air-Cooled Condensers

Although the large Freon–12 plants are equipped with water-cooled condensers, auxiliary units are commonly provided with air-cooled condensers, and this eliminates the necessity for circulating water pumps and piping.

The exterior surface of the tubes and fins on an air-cooled condenser should be kept free of dirt or any matter that might obstruct heat flow and air circulation. The finned surface should be brushed clean with a stiff bristle brush as often as necessary. When installations are exposed to salt spray and rain through open doors or hatches, care should be taken to minimize corrosion of the exterior surfaces. The finned surface is usually coated with solder and should never be painted; it may be retinned if necessary.

### Testing For Leaks

To prevent serious loss of refrigerant through leaky condenser tubes, the condenser should be tested for leakage once every two weeks. The test should always be conducted on a condenser that has not been in use for at least 12 hours. Slowly open the valves on the water side, one at a time, and insert the exploring tube of a leak detector. If this test indicates that Freon–12 gas is present, the exact location of the leak may be detected as follows:

1. Remove the water heads and listen at each section for the hissing sound that indicates gas leakage. If the leak cannot be definitely located, all the tubes must be checked. However, if the probable location of the leaky tubes is found, treat that section as follows:

2. Wash the tube heads, and with a cloth or ball of cotton clean all tubes (while wet) until the inner walls are dry and shining. Then hold the exploring tube in one end of each condenser tube for about 10 seconds. As soon as fresh air is drawn into the tube, drive a cork into each end of the tube. If necessary, repeat this procedure with all the tubes in the condenser. Before proceeding further, allow the condenser to remain in this condition for 48 hours.

3. After the tubes have been corked up for 48 hours, put 3 men on the job, one to remove corks at one end, another to remove corks at the other end and handle the exploring tube, and the third man to watch the color of the flame in the lamp. Start with the top row of tubes in the section being inspected, remove the corks simultaneously at each end of the tube, and insert the exploring tube for 5 seconds.

4. Mark any leaky tubes for later identification.

5. Leakage of any of the tube joints is indicated by the presence of oil at the joint, after the 48-hour period.

To date, this procedure has been found to be the only method which gives conclusive evidence; in most cases, this method has given satisfactory results.

## Retubing of Condensers

The general procedure for retubing condensers has been outlined in chapter 4 of this training course. One specific illustration of retubing a refrigerant condenser is as follows:

1. Drill into both ends of the faulty tube or tubes, with a $^{19}/_{32}$ inch drill, to a depth of $^{1}/_{16}$ inch less than the actual thickness of the tube sheet.

2. Insert the condenser knockout bar. Then insert, in the other end of the tube, a bar $^{1}/_{2}$ inch x 6 inches.

3. Proceed to the other end of the condenser and drive out the faulty tube by using the knockout bar.

4. Follow the above procedure for any further tube removal.

5. Cut the new tube $^{1}/_{8}$ inch longer than the over-all length of the condenser (heads removed).

6. Both ends of the tubes must be square and all inside and outside burrs removed.

7. Insert the new tube in the condenser, leaving $\frac{1}{16}$ of an inch protruding from each end.

8. Secure the spacing bar over one end of the tube.

9. Oil the rolling tool, insert it in the tube, and roll the tube into serrations.

10. Remove the spacing bar and roll that end of the tube by the above method.

11. Insert the belling tool and keep rotating while belling. Do not strike TOO HARD on the belling tool.

12. After belling both ends of the tube, grind off the ends flush with the tube sheet.

13. Open the discharge line valve into the condenser, and open any other valves necessary to get gas from the compressor into the condenser.

14. Using the pressure thus obtained, test the condenser for leaks, with the halide torch.

15. If any small leaks exist, reroll the leaking tube. (Spacers are used on the rolling tool to prevent the use of maximum rolling effect on a preliminary rolling operation. Additional rolling effect may be obtained by removing one of these spacers.)

16. Reassemble the condenser.

## EXPANSION VALVES

In order to diagnose troubles in a ship's refrigeration plant, it is essential that the MM1 or C have a thorough understanding of the principles and operation of expansion valves.

### Thermostatic Expansion Valve

FUNCTION. The thermostatic expansion valve controls the quantity of refrigerant admitted to the cooling coil and reduces the pressure of this refrigerant to that pressure maintained in the coil. The valve also operates to feed into the coil the amount of refrigerant necessary to keep the coil working at maximum effectiveness and in accordance with

heat load variation, and to prevent the flooding back of liquid refrigerant to the compressor.

Operation. It is apparent that, if the suction gas leaving the cooling coil is at the saturated vapor temperature of the refrigerant and the Freon–12 in the control bulb is also at this temperature, the control bulb pressure transmitted to the top of the valve diaphragm will be equal to the suction pressure transmitted to the lower side of the diaphragm through the equalizing line. The valve needle will be in the closed position, because of upward pressure exerted by the valve spring. The continued operation of the compressor maintains or lowers the cooling coil suction pressure, but since the valve is closed and no liquid refrigerant is supplied to the coil, the temperature of the coil rises because of the heat absorbed from the space being cooled. The Freon–12 in the control bulb is in turn heated, and its pressure increases to maintain a saturated pressure corresponding to the cooling coil suction gas temperature. The pressure on top of the power element diaphragm increases, overcomes the spring pressure, and causes the valve needle to open, thus permitting the flow of refrigerant liquid into the coil.

The liquid refrigerant is evaporated during its passage through the coil. Upon leaving the outlet end, the cold vapor cools the Freon–12 in the control bulb and decreases the upper diaphragm pressure, tending to close the valve. This reduction in valve opening reduces the quantity of refrigerant fed to the cooling coil and permits evaporation of all the liquid before the refrigerant reaches the outlet end where the control bulb is located. The refrigerant vapor becomes superheated during its passage through that part of the coil beyond the point where all liquid is evaporated.

The amount of superheat depends on the valve spring pressure exerted on the diaphragm. For a given spring setting, the valve maintains a relatively constant degree of superheat at the coil outlet, ensuring that all Freon–12 liquid is evaporated before it leaves the coil to return to the compressor.

External Equalizer for Thermostatic Expansion Valves. The external equalizing connection is provided for relatively large cooling coil installations where a considerable pressure loss may be expected to occur because of the length of coil travel or the distribution method. This equalizing line is connected to the cooling coil at a convenient point where the desired operating pressures will be reflected.

For small installations the pressure drop through the coil is correspondingly small, and the refrigerant pressure at the valve outlet is practically equal to that at the coil outlet where the control bulb is located; in such an installation the external equalizing line is unnecessary. Instead, the expansion valve is provided with an internal equalizing port, to adjust the pressure on the lower side of the diaphragm so that it will equal the pressure at the valve outlet.

Testing and Adjustment. When the thermostatic expansion valve is operating properly, the temperature at the outlet side of the valve is much lower than that at the inlet side. If this temperature difference does not exist when the system is in operation, the valve seat is probably dirty and clogged with foreign matter.

Once a valve is properly adjusted, further adjustment should not be necessary. The major trouble encountered can usually be traced to moisture or dirt collecting at the valve seat and orifice.

By means of a gear and screw ar angement, the thermostatic expansion valve is adjusted to maintain a superheat ranging approximately from 4° to 12° F at the cooling coil outlet. The proper superheat adjustment varies with the design and service operating conditions of the valve, and the design of the particular plant. Increased spring pressure increases the degree of superheat at the coil outlet and decreased pressure has the opposite effect. Many thermostatic expansion valves are initially adjusted by the manufacturer to maintain a predetermined degree of superheat, and no provision is made for further adjustments in service.

If expansion valves are adjusted to give a high degree of superheat at the coil outlet, or if the valve is stuck shut,

the amount of Freon–12 admitted to the cooling coil will naturally be reduced. With an insufficient amount of refrigerant the coil will be "starved" and will operate at a reduced capacity. Compressor lubricating oil carried with the Freon–12 vapor may tend to collect at the bottom of the cooling coils, thus robbing the compressor crankcase, and providing a condition whereby slugs of lubricating oil may be drawn back to the compressor. If the expansion valve is adjusted for too low a degree of superheat, or if the valve is stuck open, liquid Freon–12 may flood from the cooling coils back to the compressor. Should the Freon–12 liquid collect at a low point in the suction line or coil, and be drawn back to the compressor intermittently in slugs, there is danger of injury to the moving parts of the compressor.

In general, the expansion valves for air conditioning and water cooling plants (high temperature installations) must be adjusted for higher superheat than are the expansion valves for cold storage refrigeration and ship's service store equipment (low temperature installations).

If it is impossible to adjust expansion valves to the desired settings, or if it is suspected that the expansion valve assembly is defective and requires replacement, appropriate tests must be made. (First be sure that the liquid strainers are clean, that the solenoid valves are operative, and that the system is sufficiently charged with refrigerant.)

The major equipment required for expansion valve tests is as follows:

1. A service drum of Freon–12, or a supply of clean dry air at 70 to 100 psi gage. The service drum is used to supply gas under pressure. The gas used does not have to be the same as that employed in the thermal element of the valve being tested.

2. A high-pressure and a low-pressure gage. The low-pressure gage should be accurate and in good condition so that the pointer does not have any appreciable lost motion. The high-pressure gage, while not absolutely necessary, will be useful in showing the pressure on the inlet side of the

valve. Freon–12 plants are provided with suitable spare and test pressure gages.

The procedure for testing is as follows:

1. Connect the valve inlet to the gas supply with the high-pressure gage attached so as to indicate the gas pressure to the valve, and with the low-pressure gage loosely connected to the expansion valve outlet. The low-pressure gage is connected up loosely so as to provide a small amount of leakage through the connection.

2. Insert the expansion valve thermal element in a bath of crushed ice. Do not attempt to perform this test with a container full of water in which a small amount of crushed ice is floating.

3. Open the valve on the service drum or in the air supply line. Make certain that the gas supply is sufficient to build up the pressure to at least 70 psi on the high-pressure gage connected in the line to the valve inlet.

4. The expansion valve can now be adjusted. If it is desired to adjust for 10° F superheat, the pressure on the outlet gage should be 22.5 psi gage. This is equivalent to a Freon–12 evaporating temperature of 22° F, and since the ice maintains the bulb at 32° F, the valve adjustment is for 10° superheat (difference between 32 and 22). For a 5° superheat adjustment, the valve should be adjusted to give a pressure of approximately 26.1 psi gage. There must be a small amount of leakage through the low-pressure gage connection while this adjustment is being made.

5. To determine if the valve operates smoothly, tap the valve body lightly with a small weight. The low-pressure gage needle should not jump more than 1 psi.

6. Now tighten the low-pressure gage connection so as to stop the leakage at the joint, and determine if the expansion valve seats tightly. With the valve in good condition, the pressure will increase a few pounds and then either stop or build up very slowly. With a leaking valve, the pressure will build up rapidly until it equals the inlet pressure.

7. Again loosen the gage so as to permit leakage at the gage connection; remove the thermal element, or control bulb,

from the crushed ice, and warm it with the hand or place it in water that is at room temperature. When this is done, the pressure should increase rapidly, showing that the power element has not lost its charge. If there is no increase in pressure, the power element is dead.

8. With high pressure showing on both gages as outlined above, the valve can be tested to determine if the body joints or the bellows leak. This can be done by using a halide leak detector. When performing this test, it is important that the body of the valve have a fairly high pressure applied to it. In addition, the gages and other fittings should be made up tightly at the joints so as to eliminate leakage at these points.

REPLACEMENT OF VALVE. If it is evident that the expansion valve is defective, it must be replaced. Often it is possible to replace a faulty power element or other part of the valve without having to replace the entire assembly. When replacement of an expansion valve is necessary, it is important to replace the unit with a valve of the same capacity and type, designed for Freon–12 systems.

### Automatic Expansion Valve

Automatic expansion valves are generally similar in construction to thermostatic valves except that the thermostatic element is omitted. The refrigerant pressure in the cooling coil operates on the lower side of the diaphragm and atmospheric pressure operates on the upper side. The amount of valve opening depends upon the pressure existing in the coil.

As the operation of the compressor lowers the coil pressure, there is a corresponding decrease in pressure on the lower side of the diaphragm; when this pressure becomes less than the atmospheric pressure on the upper side, the diaphragm is depressed and the valve opens. The pressure at which the valve will open can be predetermined by an adjustment of the valve. As the compressor continues to operate, the needle valve remains open enough to maintain the refrigerant evaporating pressure. When the compressor

stops, the coil pressure increases and the valve automatically closes. Thermostatic expansion valves have proved to be more satisfactory than automatic expansion valves for refrigeration plant applications required for naval vessels.

### Hand Expansion Valve Bypass

A bypass line equipped with a manually operated expansion valve is installed around the strainer and the cooling coil liquid control valve assembly to permit repair or cleaning. The hand expansion valve is generally similar in design to the other Freon–12 stop valves installed in refrigeration systems, except that the valve disk is sometimes specially shaped to permit accurate adjustment of flow. Hand expansion valves should be used only for emergency purposes, since there is the possibility of flooding liquid refrigerant back to the compressor.

## SWITCHES

In order to trouble-shoot or diagnose switch troubles, it is essential that you have a good understanding of PRESSURESTATS and THERMOSTATS. A pressurestat is an electric switch actuated by pressure from an outside source. The thermostat is actuated by temperature or heat on a specially prepared thermo-bulb, filled with a substance that expands and contracts with any change in temperature.

A switch that cuts out when there is an increase in pressure or temperature is known as a DIRECT ACTING switch. When the pressure or temperature is decreased, the switch cuts in. The high-pressure switch is a direct acting switch. A REVERSE ACTING switch is one that cuts in on an increase of pressure or temperature and cuts out on a decrease of pressure or temperature. The low-pressure cut-out, cooling thermostat, and water failure switches are reverse acting switches.

### Low-Pressure Cut-Out Switch

In the compressor suction line between the suction line stop valve and the compressor, a connection leads to the low-pressure cut-out switch (often called the suction pressure control switch). This switch is located on the compressor base or

on a panel adjacent to the compressor. The refrigerant suction pressure acts on the metallic bellows of the power element of the switch and produces movement of a lever mechanism operating electrical contacts. These contacts are in a circuit connected to the compressor motor controller panel.

When all the solenoid valves have closed, the suction pressure drops until it reaches the setting of the low-pressure cut-out switch (approximately 2 psi). When the suction pressure is 2 psi, the switch opens, stopping the compressor. When one or more solenoid valves open, the suction pressure rises, causing the switch to close its contacts and start the compressor. The low-pressure cut-out switch has a differential of about 18 psi; it stops the compressor when the pressure drops to 2 psi; and it restarts the compressor at about 20 psi. The low-pressure cut-out provides automatic control of the system. It halts the system when the desired degree of coolness in all spaces has been reached, thus making possible economical operation.

### High-Pressure Cut-Out Switch

A switch connected to the high-pressure line serves as a safety device to prevent dangerously high pressure from developing within the system. When the discharge pressure rises above 150 psi (the usual setting) the switch opens, stopping the compressor and shutting down the system. The switch has a differential of about 25 psi. When the high pressure decreases to 125 psi, the switch closes, and automatically restarts the compressor.

### Solenoid Control Switch

A solenoid control or thermostatic switch controls the circuit to each solenoid valve coil. When the temperature of the compartment in which the control bulb or element is located has been decreased to the desired point, the switch opens the circuit. These switches are usually provided with differential as well as range adjustment mechanisms. It is good practice to set the differential adjustment for 3° F or less between the cut-in and cut-out points. The cut-out setting of solenoid valve control switches used for water chillers

should be kept at a temperature somewhat above 32° F, to prevent freezing.

### Water Failure Switch

The water failure switch is primarily a safety device to shut down the compressor before the head pressure builds up to the point where the high-pressure switch cuts out the compressor. The water pressure cut-out point is established by the corresponding head pressure.

To determine the cut-out point, slowly close down on the inboard water valve to the condenser and allow the head pressure to build up to a point of 10 psi below the cut-out point of the compressor high-pressure switch. After establishing the cut-out point, slowly open the condenser water supply and allow the head pressure to drop to within approximately 10 psi of normal. Then check the water pressure gage, which should be the cut-in point for the water failure switch.

Cut-in and cut-out points established when a ship was in cold waters may have to be readjusted if the ship moves to tropical waters. Once the switch is set in tropical waters, it will not be necessary to readjust the switch if the ship moves back to cold water.

After the cut-in and cut-out points are established, the switch is adjusted with the same procedure that is used in setting the low-pressure cut-out.

## DETECTION AND CORRECTION OF TROUBLES

Faulty operation of the refrigerating plant is indicated by various definite symptoms. These symptoms may indicate the presence of one or more conditions in the plant. Each condition must be eliminated by specific corrective measures. Space does not permit a detailed discussion here of abnormal plant conditions, but you can find complete information in the manufacturer's instruction book furnished with each refrigeration plant. The following chart, listing symptoms, their causes, and the corrective measures to be taken, will assist you in correcting faulty operation quickly and efficiently.

TROUBLE-DIAGNOSIS CHART

| Symptom or difficulty | Condition may be due to— | Correction |
|---|---|---|
| High suction pressure | Overfeeding of expansion valve | Regulate expansion valve, check thermal element attachment. |
| | Leaky suction valves | Examine valve disks, or piston rings; replace if defective. |
| | Improper functioning of low-pressure control switch. | Readjust or replace switch. |
| | Discharge valves leak slightly | Examine valves. If leaking, replace if necessary. |
| Low suction pressure | Restricted liquid line, expansion valve, or suction strainers. | Remove, examine, and clean strainers. |
| | Insufficient refrigerant in system | Check for refrigerant shortage. |
| | Too much oil circulating in system | Check for too much oil in circulation. Remove oil. (See "Oil leaves crankcase".) |
| | Improper adjustment of expansion valves | Adjust valve to give more flow. |
| | Coils in refrigerators clogged with frost | Defrost coils. |
| | Thermal bulb of expansion valve has lost charge. | Detach thermal bulb from suction line and hold in the palm of one hand, with the other hand gripping the suction line; if flooding through is observed, bulb has not lost its charge. If no flooding through is noticed, test and replace expansion valve if necessary. |
| | Forced air cooler air flow restricted or fan inoperative. | Check for air obstruction, dirty filters, or electrical operation. |
| | One or more solenoid valves closed | Check electrical solenoid circuit for failure and repair. |
| | Compressor capacity in excess of existing compartment heat load. | Reduce speed of compressor or adjust compressor capacity reduction where provided. |
| Low suction line temperature | Excessive liquid refrigerant circulating in system. | Check for excess and remove. Check expansion valve adjustment and regulate. |
| High suction line temperature | Shortage of refrigerant in system | Check, test for leaks and add refrigerant as required. |
| High discharge pressure | Air or noncondensable gas in system | Purge air from condenser. |
| | Inlet water warm | Increase quantity by adjusting water-regulating valve. |
| | No water or insufficient quantity of water flowing through condenser. | Adjust water-regulating valve, open manual valves, or start pump. |
| | Condenser tubes clogged | Clean condenser tubes and water boxes. |
| | Too much refrigerant in system (condenser tubes submerged in liquid refrigerant). | Draw off excess refrigerant into service drum. |
| | Condenser improperly vented | Vent condenser water boxes. |
| | Air-cooled condenser dirty or receiving insufficient air. | Clean or remove obstructions. Check space ventilation for adequate supply of cool air and correct. |

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|---|---|---|
| Low discharge pressure | Too much water flowing through condenser. | Regulate water valve. |
| | Water too cold or unthrottled | Reduce quantity of water. |
| | Liquid refrigerant flooding back from cooling coils. | Change expansion valve adjustment, examine fastening thermal element. |
| | Leaky discharge valve | Examine. If leaking, replace. |
| High discharge temperature | Air or noncondensable gas in system | Purge air from condenser. |
| Low discharge temperature | Excessive liquid refrigerant in system | Check expansion valve setting and adjust. |
| Low oil pressure | Dirt in oil pump or strainer | Stop compressor. Check oil gage for accuracy. Clean, repair, or replace oil strainer and pump. |
| Excessive oil pressure | Clogged oil distribution lines | Stop compressor. Check oil gage for accuracy. Pump down, clean oil lines. |
| Oil leaves crankcase | Refrigerant flooding back to compressor | Adjust expansion valve and check for proper mounting of thermal elements. |
| | Leaking piston rings or worn cylinder | Replace rings, cylinder sleeves, or compressor. Rebore and refit. |
| | Expansion valves leaking | Valve seats and stem may be corroded from passage of refrigerant vapor. Check and replace if required. |
| | Overcharge of oil | Check oil sight glass and remove excess. Check for continuing return and repeat process until oil level is constant. |
| Oil does not return to crankcase | Expansion valve not supplying cooling coil with sufficient refrigerant. | Check operation of expansion valve and adjust, if required. |
| | Valve in oil return line closed or stuck shut | Open. |
| | Oil trap or pocket in cooling coil or suction line piping. | Locate, open, and drain. |
| Oil sight glass shows presence of oil foaming. | Excessive liquid refrigerant returning to compressor. | Check expansion valve adjustment or leaking hand expansion valves. Adjust, repair, or replace. |
| Crankcase and cylinder temperature relatively warm with low suction pressure. | Shortage of refrigerant | Test for shortage, add refrigerant if required, test for leaks. |
| Crankcase temperature relatively cooler than suction line with low pressure suction. | Excessive oil is circulating in system | See "Oil leaves crankcase." |
| Crankcase and cylinder temperature relatively cold, sweating, or frosting. | Liquid refrigerant being returned to compressor. | Check expansion valve setting, adjust. Check for proper mounting of thermal element. |

TROUBLE-DIAGNOSIS CHART—Continued

| Symptom or difficulty | Condition may be due to— | Correction |
|---|---|---|
| Compressor noisy | Vibration because the compressor is not rigidly bolted to foundation. | Bolt down rigidly. |
| | Too much oil in circulation causing hydraulic knock. | Check oil level. |
| | Slugging due to flooding back of refrigerant. | Expansion valve open too wide; adjust. Thermo-bulb incorrectly placed or loose; check and relocate or fasten. |
| | Wear of parts such as piston pins, bearings, etc. | Determine location of cause. Repair compressor. |
| Water supply pressure too low | Water pump suction line restricted | Check for closed valves, check strainer and clean. |
| | Pressure-reducing valve in fire flushing line improperly adjusted. | Check and readjust. |
| Water supply pressure too high | Pressure-reducing valve improperly adjusted. | Check and adjust. |
| | Water valves open too wide | Check and close to proper pressure. |
| Water overboard temperature too low | Excessive water flow through condenser | Correlate with discharge pressure and check water regulating valve operation, adjust if necessary. (See "Water supply pressure too high.") |
| Water overboard temperature too high | Restricted water flow through condenser | Correlate with discharge pressure. Check water-regulating valve and adjust, if necessary. (See "Water supply pressure too low.") |
| Liquid line refrigerant temperature too warm. | Shortage of refrigerant | Test for shortage, charge with refrigerant, test for Freon-12 leakage. |
| Liquid line refrigerant temperature too cold. | Excessive liquid refrigerant circulating in system. | Check for overcharge and remove excess. Check expansion valve setting and thermal element mounting; if improper adjust. |
| | Excessive oil in circulation | See "Oil leaves crankcase." |
| Sight flow indicator shows bubbles in refrigerant. | Shortage of refrigerant | Test for shortage, charge with refrigerant, test for Freon-12 leakage. |
| Ice-making tank temperature too high | Automatic controls not functioning | Check electrical circuit for open switches, blown fuses, burnt solenoid coil, and repair or replace. Check adjustment of control switch. |

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|---|---|---|
| | Brine solution too weak and freezing | Check salinity of brine for proper density. (Chapter 59, art. 345 of BuShips *Manual.*) Add stronger solution. |
| | Expansion valve not feeding sufficient refrigerant. | Check for improper adjustment, or moisture at valve orifice. Adjust or clean. Put dehydrator in operation if moisture is in evidence. |
| Ice-making tank temperature too low | Automatic controls not functioning | Check solenoid valve switch setting and adjust if necessary. |
| | Hand expansion valve leaking | Check position of valve for tight closing. Check for dirt or corrosion at seat and pin. Clean, repair, or replace. |
| Compartment temperature too high | Automatic controls not functioning | Check solenoid valve switch or thermostat setting, electrical circuit, fuses, and solenoid coil. Repair or replace. If there is a forced air cooler, check to see that fan is operating. |
| | Excessive frost on cooling coils | Defrost. |
| | Expansion valve not feeding sufficient refrigerant. | Check for improper adjustment, or moisture at valve orifice. Adjust or clean. Put dehydrator in operation if moisture is present. |
| | Airflow restricted on forced air coolers | Check filters, duct work obstructions, and fan operation. Clean and repair as required. |
| | Excessive infiltration of uncooled air | Check unwarranted traffic in and out of compartment. Take steps to limit traffic as to personnel and entrance periods. Check compartment openings and door gaskets. Repair or replace. |
| | Introduction of warm and/or moist product | Temporary. If within the capacity of equipment, temperature will eventually return to normal. Start an additional compressor if system is arranged for isolating loads carried by more than one unit in operation. |
| Compartment temperature too low | Automatic controls not functioning | Check solenoid valve switch or thermostat setting, electrical circuit, fuses, and solenoid coils. Repair or replace. |
| | Hand expansion valve leaking | Check position of valve for tight closing. Check for dirt, or corrosion at seat and pin. Clean, repair, or replace. |
| Liquid refrigerant cycling through the cooling coil with wide variation in superheat at thermal element location. | Excessive oil circulating through system | Check other symptoms for a like condition. (See "Oil leaves crankcase" and "Oil does not return to crankcase.") |
| | Moisture or ice at thermal element contact with suction line affecting true operation. | Remove, dry, and properly insulate. |
| | Expansion valve defective | Check thermal element for response. Repair or replace. |
| | Thermal element located in such a position to be affected by air flow. | Remove and relocate; insulate. |
| | Expansion valve too large or has improper thermostatic charge. | See instruction book furnished with equipment for selected size and type. Install proper valve. |

### Trouble-Diagnosis Chart—Continued

| Symptom or difficulty | Condition may be due to— | Correction |
|---|---|---|
| Liquid refrigerant cycling through the cooling coil with wide variation in superheat at thermal element location. | Moisture in expansion valve port or working parts. | Check heat valve body slowly taking care not to damage power element and gaskets. Heat will temporarily free valve parts and resume automatic operation. If moisture is present disassemble valve, clean and replace. Put dehydrator into service. |
| Liquid refrigerant carrying through the coil and far beyond the thermal element location with little superheat at this point. | Expansion valve open too wide | Adjust to close. |
| | Thermal element making poor contact with suction piping. | Remove, clean both surfaces, and insulate. |
| | Thermal element improperly located or insulated. | Remove, locate properly, and insulate. |
| | Expansion valve leaking | When compressor shuts down, check by listening at valve for a hissing sound. Check for dirt or corrosion of seat. Clean, repair, or replace. |
| Liquid refrigerant carrying partially through the coil with considerable superheat at thermal element location. | Moisture in expansion valve port or working parts. | See same condition and correction as above. |
| | Liquid line strainer clogged or dirty | Remove, clean, and replace. |
| | Expansion valve improperly adjusted | Check superheat and adjust. |
| | Shortage of refrigerant | Check shortage, test for leaks and charge. |
| | Expansion valve thermal element improperly located. | Check and relocate. |
| | Expansion valve too small | See instruction book furnished with equipment, and install proper size and type. |
| | Refrigerant gas in liquid line | Check for excessive pressure loss in liquid line. Open valves or restrictions affecting loss. Check sub-cooler, if installed, for proper operation. |
| | Pressure drop through cooling coils excessive. | Check for restrictions, oil traps or valves partially closed. Drain oil or open restrictions as applicable. |
| | Expansion valve power element has lost charge of refrigerant. | Remove thermal element and heat by hand temperature. If not responsive, replace power assembly or valve. |
| | Expansion valve equalizer line closed or restricted. | Check, and open or replace. |
| | Expansion valve thermal element being affected by refrigerant from another cooling coil circuit. | Check location of thermal element. Remove and properly locate. |
| Compressor will not start | Overload tripped, fuses blown | Reset overload, replace fuses, and examine for cause of condition. |
| | Switch out | Throw in switch. |
| | No charge of gas in system operated by low-pressure control switch. | With no gas in system there is insufficient pressure to throw in low-pressure control. Recharge system with refrigerant; check and repair leaks. |

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|---|---|---|
| | Solenoid valves closed | Examine coil, switch, etc.; if defective or out of adjustment, replace or adjust. |
| | No flow of circulating water through condenser to actuate water-failure switch. | Provide condenser circulating water. |
| Compressor runs continucusly | Shortage of refrigerant | Test for shortage of refrigerant; if insufficient, add proper amount. Test system for leaks. |
| | Discharge or suction valves leak badly | Test valves; if leaking, repair or replace. |
| | Head gasket blown between cylinders | Replace gasket. |
| | Improper functioning of low-pressure control switch. | Adjust or replace switch. |
| | Overloaded compressor | Start an additional compressor if system is arranged for isolating loads carried by more than one unit in operation. |
| | Stuck-open or leaky relief valve | Overhaul relief valve. |
| Compressor short cycles on high-pressure cut-out. | High-pressure cut-out incorrectly set. (See "High head pressure.") | Check setting of high-pressure cut-out; switch should throw out at about 150 pounds head pressure. |
| Compressor short cycles on low-pressure control switch. | Low-pressure control incorrectly set. (See "Low suction pressure.") | Check setting and adjust. |
| Water valve chatters | Water pressure too high | Reduce water pressure by adjusting water pressure-reducing valve or throttling stop valve. |
| Water runs continuously when compressor is shut off. | Water-regulating valve open too wide | Readjust valve to give correct head pressures corresponding to water inlet temperature and condensing pressure. |
| | Dirt under seat of water-regulating valve | Remove valve from lines, disassemble, and examine; replace defective parts, clean and reassemble. If valve then does not function properly, replace. |
| | Valve mechanism stuck | Remove and disassemble. Clean valve seats and valve pins, lubricate, adjust packing, etc. |
| | Pump motor controller contact stuck shut | Adjust. |
| Head gasket leaks | Head bolts stretched, or washers crushed | Examine gaskets; replace if necessary. Tighten head bolts. Replace washers. |
| | Oil or refrigerant slugging | Check operating conditions for flooding of refrigerant back to compressor. Correct. |
| Oil seepage at shaft seal connection is excessive. | Failure of shaft seal | Test, repair, or replace crankshaft seal. |
| Oil seepage at refrigerant system piping and compressor connections. | Leakage of refrigerant | Test; remake connections or provide replacement gaskets, as required. |

## SAFETY PRECAUTIONS

When working with Freon–12 refrigeration systems, observe the following safety precautions:

1. Inspect the oil level in the compressor before starting.
2. Inspect the oil pressure in the forced-feed compressor systems.
3. Don't admit any air into the system.
4. Don't allow dirt to enter the system.
5. Prevent mechanical injury and depreciation.
6. Exercise caution when starting the compressors.
7. Do not operate the compressors with emergency piping interconnections open.
8. Alternate compressor operation.
9. Check the system regularly.
10. Test the system for leaks.
11. Don't permit the crankcase to become cold or frosted.
12. Don't permit the suction scale trap to become frosted.
13. Drain water from idle condensers.
14. Guard against trapped Freon expansion pressures.
15. Wear goggles in order to prevent liquid Freon from getting in your eyes when you charge or purge the system, or open it to make repairs.

If liquid Freon–12 accidentally comes in contact with the eyes, introduce drops of sterile mineral oil, or olive oil, as an irrigant. TAKE EVERY PRECAUTION TO SEE THAT THE VICTIM DOES NOT RUB HIS EYES. If possible, the person suffering an injury of this nature should be taken at once to the medical officer.

If liquid Freon–12 comes in contact with the skin, the injury should be given the same treatment as though the skin had been frostbitten or frozen.

A person overcome in a space that lacks oxygen because of high concentrations of Freon–12 must be given artificial respiration.

## SUMMARY

The MM1 or C is responsible for supervising and training personnel in the operation, maintenance, and repair of refrigeration equipment. Constant vigilance should be maintained over the refrigeration system, to ensure its proper care and operation. It is considered good practice to make a complete check, every hour, of all temperatures and pressures throughout the system, and of the oil level in the compressor crankcase.

As an MM1 or C, you should know how to charge the Freon–12 system as well as open a charged system; how to dehydrate and clean various parts; and how to detect leaks throughout the system.

Your knowledge of the Freon–12 compressor units and lubrication system should comprise the following: how to diagnose compressor troubles, and what to do about them; what steps must be taken in dismantling and reassembling compressors; and what precautions must be observed in removing, replacing, or repairing compressor internal parts.

Your understanding of condensers should include: how to check water-cooled condensers for performance; how to clean condenser tubes and air-cooled condensers properly; how to minimize electrolytic corrosion of condenser parts coming in contact with sea water; and how to remove and replace condenser tubes.

## QUIZ

1. How often should a complete check be made of all temperatures throughout the system, and of the oil level in the compressor crankcase?
2. How often should the compressor belts be checked for tension?
3. If a shortage of refrigerant exists in the system, what will generally be indicated?
4. What device is generally employed to test the refrigeration system for leaks?
5. Pressure testing for tightness is generally performed by what personnel?
6. The time required for the dehydration and evacuation process depends upon what factors?

7. The inability to obtain a temperature as low as 35° F in the vacuum indicator, within a reasonable length of time, may result from what cause(s)?
8. When should the drying agent in the dehydrator be reactivated?
9. How is the reactivation process accomplished?
10. When oil is being removed from the compressor, why should the drain plug NOT be completely removed?
11. When should the cleanliness of the lubricating oil be checked?
12. What indicates a faulty compressor valve?
13. How may compressor discharge valves be tested?
14. When should the compressor suction valve efficiency of new Freon–12 units be checked?
15. What is likely to occur if any part of the compressor is opened while under a vacuum?
16. How should all compressor parts be treated before reassembling the unit?
17. When can an over-all check for water-cooled condenser performance be used to indicate the condition of the condenser surface?
18. How often should condensers be tested for leakage?
19. What unit controls the quantity of refrigerant admitted to the cooling coil, and reduces the refrigerant pressure from that existing in the condenser to that maintained in the coil?
20. If the thermostatic expansion valve is adjusted to give a high degree of superheat at the coil outlet, or if the valve is stuck, what will be indicated?
21. What type of reverse acting switches cut in on an increase of pressure or temperature?
22. What should be done to correct a high Freon–12 suction line pressure resulting from overfeeding of the expansion valve?
23. What steps should be taken to correct excessive oil pressure in the compressor?
24. What will cause a very warm liquid line refrigerant temperature?
25. What should be used immediately as an irrigant for the eyes after contact with Freon–12?

# CHAPTER 12

## AIR CONDITIONING

Air conditioning is the science of establishing and maintaining the atmosphere of an enclosed space at a specified temperature, humidity, and purity. In the broadest sense of the term, air conditioning involves heating, cooling, humidifying, dehumidifying, circulating, and purifying the air.

As early as 1903, two methods of air conditioning were devised by Dr. Willis H. Carrier and Setard W. Crammer. These men worked independently. The former was interested primarily in comfort air conditioning and the latter in an improvement of industrial methods for manufacturing cotton textiles. Crammer is credited with the use of the term "air conditioning," which appears in his book on manufacture of cotton materials.

Aboard ship, the primary purpose of air conditioning is to keep personnel comfortable, alert, and physically fit at battle stations. Within the enclosed quarters of a ship during general quarters, circulation of the air tends to become very poor, and the heat as well as the moisture given off by the men's bodies increases the temperature and moisture content of the air. Research has shown that the efficiency of the human body is lowered when air temperatures and moisture content rise above certain limits, and when there is a lack of air circulation. Therefore, proper air conditioning of the ship is very important.

Air conditioning is also needed for the protection of equipment, especially electrical apparatus. The large amount of

moisture in the air given off daily from the bodies of the crew, from cooking, batteries, and bilges, would condense on any cool surface.

## THEORY OF AIR CONDITIONING

Human comfort is influenced to a great extent by the humidity, or amount of moisture present in the atmosphere. The common expression, "It isn't the heat; it's the humidity," is an indication of the popular recognition of the discomfort-producing effects of moisture-laden air in hot weather. Extremely low moisture content also has undesirable effects on the human body. The measurement and control of the moisture content of the air is an important phase of air conditioning engineering.

### Saturated Air

The air holds varying amounts of water vapor, and as temperature rises, the amount of moisture that the air can hold increases. But for every temperature there is a definite limit as to the amount of moisture that the air is capable of holding. When air at a given temperature attains this maximum amount of moisture, it is known as saturated air.

### Dew Point

The saturation point is usually called the dew point. If the temperature of saturated air falls below its dew point, some of the water vapor in the air must condense to water. The dew that appears on foliage in the early morning, when there is a drop in temperature, is such a condensation. The "sweating" of cold water pipes also is the result of water from the air condensing on the cold surface of the pipes.

### Absolute and Specific Humidity

The amount of water vapor in the air is expressed in terms of the weight of the moisture. This weight is usually given in grains (7,000 grains equal 1 pound). Absolute humidity is the weight of water vapor in grains per cubic foot of air.

Specific humidity is the weight of water vapor in grains per pound of dry air. It should be understood that these definitions refer only to moisture in the vapor state, and not in any way to the moisture (such as fog, rain, or dew) that may be present in the liquid state.

### Relative Humidity

Relative humidity is the ratio of the weight of water vapor in a sample of air to the weight of water vapor that the same sample of air could contain if saturated. This ratio is usually stated as a percentage. For example, when air is fully saturated, its relative humidity is 100 percent. When air contains no moisture at all, its relative humidity is zero percent. If air is half saturated, its relative humidity is 50 percent.

As far as comfort and discomfort resulting from humidity are concerned, it is the relative humidity and not the absolute or specific humidity that is the important factor. This can be easily appreciated from the discussion that follows.

Moisture always travels from regions of greater wetness to regions of lesser wetness, just as heat travels from regions of higher temperature to regions of lower temperature. If the air above a liquid is saturated, the two are in equilibrium and no moisture can travel from the liquid to the air; that is, the liquid cannot evaporate. If the air is only partially saturated, some moisture can travel to the air; that is, some evaporation can take place.

Suppose the specific humidity of the air is 120 grains per pound of dry air. This is the actual weight of the water vapor in the air. If the temperature of the air is 76° F, the relative humidity is then nearly 90 percent—that is, the air is nearly saturated. Although the body may perspire freely, the perspiration does not evaporate rapidly—because the air already contains nearly all the moisture it can hold—and a general feeling of discomfort results.

However, if the temperature for the air were 86° F, the relative humidity would then be only 64 percent. That is, although the absolute amount of moisture in the air is the same, the relative amount is less, because at 86° F the air

is capable of holding more water vapor than it can hold at 76° F. The body is now able to evaporate its excess moisture and the general feeling is much more agreeable, even though the temperature of the air is 10° hotter. Control of relative humidity is of extreme importance in air conditioning.

## HEAT OF THE AIR

The heat of air is considered from three standpoints—differentiated as sensible, latent, and total heat.

SENSIBLE HEAT is that measured by the household, or dry-bulb, thermometers. This is the temperature of the air itself, without regard to any humidity it may contain. It may be best to emphasize this by stating that sensible heat is the heat of dry air.

Air nearly always contains more or less moisture. Conditions of complete absence of moisture are rare, occurring perhaps only in desert regions. Any water vapor present, of course, contains the LATENT HEAT, which is generally referred to as the latent heat in the air.

Any mixture of dry air and water vapor—that is, air as we usually find it—contains both sensible and latent heat. The sum of the sensible heat and the latent heat in any sample of air is called the TOTAL HEAT of the air. Zero degrees is usualy taken as a convenient starting point from which to measure total heat.

## THREE AIR TEMPERATURES

Inasmuch as air conditioning deals with these various heats of the air as well as the condensation of moisture, three different temperatures are involved in air conditioning operations. These are the dry-bulb, wet-bulb, and dew-point temperatures.

### Measurement of Air Temperatures

DRY-BULB TEMPERATURE. This is the temperature of the sensible heat of the air, as measured by an ordinary thermometer. Such a thermometer in air conditioning engineering is referred to as a dry-bulb thermometer, because its bulb is dry, in contrast with the wet-bulb type next described.

Wet-Bulb Temperature. This temperature is best explained by a description of the wet-bulb thermometer. This is an ordinary thermometer, with a loosely woven cloth sleeve or wick placed around its bulb and then wet with water. The fabric must be clean and free from oil and wet thoroughly with clean fresh water. The water in the sleeve or wick is caused to evaporate by a current of air at high velocity. This evaporation withdraws heat from the thermometer bulb, lowering the temperature a number of degrees. The difference between the dry-bulb and wet-bulb temperatures is called the wet-bulb depression. The wet-bulb temperature is the same as the dry-bulb when the air is saturated (that is, when evaporation cannot take place). The condition of saturation, however, is unusual, and a wet-bulb depression is normally expected.

In air conditioning work, the wet-bulb and dry-bulb thermometers are usually mounted side by side on a frame, to which a handle or short chain is attached so that the thermometers may be whirled in the air, thus providing a high-velocity air current that promotes evaporation. Such a device is known as a SLING PSYCHROMETER. The psychrometer must be whirled around rapidly, at least four times per second. When the wet-bulb thermometer is examined at intervals, its temperature reading will be found to be dropping; the reading below which no further drop is observed gives the correct wet-bulb temperature.

Dew-Point Temperature. The dew point depends upon the amount of water vapor in the air. If air at a certain temperature is not saturated, and the temperature is lowered, a point is finally reached at which the air IS SATURATED for a lower temperature and condensation of the moisture then begins. This point is the DEW-POINT TEMPERATURE of the air for the quantity of water vapor present.

### Relationships Between the Three Air Temperatures

The definite relationships between the three temperatures should be clearly understood. These relationships are:

1. When the air contains some moisture but is not saturated, the dew-point temperature is lower than the dry-bulb temperature, and the wet-bulb temperature lies between them.

2. As the amount of moisture in the air increases, the differences between the temperatures become less.

3. When the air is saturated, all three temperatures are the same.

## PSYCHROMETRIC CHART

There is a relationship between dry-bulb temperature, wet-bulb temperature, dew-point temperature, specific humidity, and relative humidity. Given any two, the others can be calculated. The relationship can be shown on a psychrometric chart (fig. 12–1). In air conditioning it is customary to use this chart, since reading measurements from the chart is far easier than calculating these measurements from two given factors.

Note that in this chart the wet-bulb and dew-point temperature scales lie along the same line, which is the 100-percent relative humidity line. The dew-point temperature lines, however, run horizontally, and the wet-bulb temperature lines run obliquely down to the right. To use the chart,

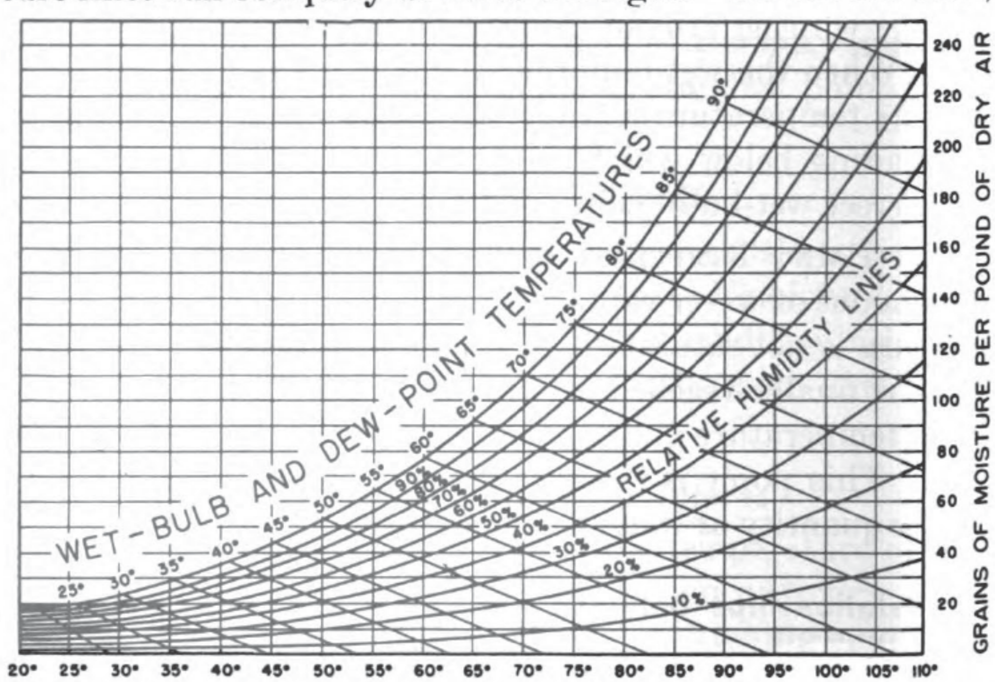



Figure 12–1.—Psychrometric chart.

take the point of intersection of the lines of the two known factors, and from this point follow the lines of the unknown factors to their numbered scales and read the measurement.

Suppose the dry-bulb temperature were 70° F and the wet-bulb temperature 60° F, you would determine the dew-point temperature and the relative humidity in the following manner. Note the point of intersection between the dry- and wet-bulb temperature lines. From this point, follow along the dew-point line (horizontal) to the dew-point scale. The dew-point temperature is 53.6° F, the relative humidity is 56 percent (read by interpolating the reading at the intersection point between curved relative humidity lines).

If the dew point were to remain at 53.6° F, and the air were to be raised to the dry-bulb temperature of 80° F, what would be the relative humidity? Follow the dew-point line to the 80° F dry-bulb temperature line; by interpolation, the relative humidity is 40.5 percent.

If the dry-bulb temperature is 80° F and the dew-point temperature 70° F, what will be the relative humidity when the dry-bulb temperature of the air is raised to 90° F? Note the point of intersection of the horizontal line running from the 70° F line with the vertical 80° F line. Follow this horizontal line to the 90° F dry-bulb line; at that point, the relative humidity reads 52 percent.

The actual weight of any amount of water vapor in air at any temperature can be read on the chart from the scale at the right-hand edge. Note the 70° F dry-bulb temperature line. From the intersection on the line of the various relative humidity percentage lines, follow the horizontal line to the right-hand scale, to read the number of grains of water vapor per pound of dry air. At the bottom is zero moisture, or completely dry air. At the top is 100 percent saturation, such saturated air at 70° F holding a maximum of 110.5 grains per pound. The weight of water vapor that is contained in air at 70° F can be found, for any percentage of saturation, by starting with the given relative humidity point on the 70° F dry-bulb line, and following the horizontal line to the right-hand scale.

## AIR MOTION

It is a well-known fact that when the air in a room is motionless, the room soon feels stuffy to its occupants, even though the air may be quite fresh. On the other hand, air that is somewhat stale does not feel stuffy if it is kept stirred; although it may, perhaps, be too warm, it is nevertheless bearable. Stirring of the air creates three effects, all adding up to a feeling of greater comfort. One is a purely sensory effect, another affects humidity, and the third affects temperature. The three are closely interrelated and depend upon the velocity of the air motion.

### Sensory Effect of Air Motion

When the air has a gentle motion—a velocity of 20 to 50 feet per minute (fpm)—the tactile sensory nerves in the skin are stimulated, and a feeling of greater comfort is experienced than when the air is completely still.

### Effect of Air Motion on Humidity

The body is always evaporating moisture, even though the evaporation may be at such a slow rate that it is not perceptible as perspiration. If the air is still, this evaporated moisture stays close; it forms, with the heat also given off, a damp, hot blanket around the body. Within such a blanket, air is less able to absorb the evaporation from the body; hence a feeling of discomfort ensues. But if the air is stirred, the convection currents thus formed carry away the moisture as rapidly as it is given off, and a normal rate of evaporation is maintained.

### Effect of Air Motion on Temperature

The human body is constantly giving off heat to the air around it, by conduction. If the air is still, the air close to the body gradually becomes heated, and this heat is not carried away by convection currents. Thus, although the average temperature of the air in a room may remain nearly

constant, the body itself is in air of higher temperature. If the air is in motion, however, the heat coming from the body is carried away by convection before it can build up.

## BODY HEAT BALANCE

Ordinarily the body remains at a fairly constant temperature of 98.6° F. It is very important that this body temperature be maintained, and since there is a continuous heat gain from surrounding and from interior processes, there must also be a continuous outgo to maintain a balance. This excess heat must be absorbed by the surrounding air. As the temperature and humidity of environment vary, the body automatically regulates the amount of heat which it gives off. However, this ability to adjust to varying environmental conditions is limited. Furthermore, although the body may adjust to certain atmospheric conditions, it may do so with a distinct feeling of discomfort. The following discussion will familiarize you with the way in which atmospheric conditions affect the body's ability to maintain a heat balance.

### Body Heat Gains

The body gains heat (1) by radiation, (2) by convection, (3) by conduction, and (4) as a byproduct of physiological processes that take place within the body.

The heat radiation gain comes from our surroundings, but since heat always travels from regions of higher temperature to regions of lower temperature, the body receives heat only from those surroundings that have a temperature higher than 98.6° F. The greater source of heat radiation is the sun. Indoor heat radiation is gained from heating devices, operating machinery, hot steam piping, etc.

The heat convection gain comes from currents of heated air only. Such currents of air may come from a galley stove or engine.

The heat conduction gain comes from objects with which the body, from time to time, is in contact.

Most of the body heat comes from within the body itself. Heat is being continuously produced inside the body by the

oxidation of foodstuffs and other chemical processes, by friction and tension within the muscle tissues, and by other causes as yet not completely identified.

## Body Heat Losses

There are two types of heat losses; one is loss of sensible heat, and the other, loss of latent heat. Sensible heat is given off by three methods: (1) radiation, (2) convection, and (3) conduction. Latent heat is given off by evaporation.

The body is usually at a higher temperature than that of its surroundings, and therefore radiates heat to walls, floors, ceilings, and other objects. This action is called heat radiation loss. The temperature of the air does not influence this radiation, except as it may alter the temperature of such surroundings. The heat convection loss occurs when the heat is carried away from the body by convection currents, both by the air coming out of the lungs and by exterior air currents. The heat conduction loss is caused by bodily contact with colder objects or substances.

The heat loss by evaporation is the loss of heat due to the cooling effect of vaporization of the body's moisture. Under normal air conditions, the body gets rid of excess heat by this method. The heat inside the body is sensible heat; in the evaporation process, it becomes latent heat. The rate of evaporation, and hence of heat loss, depends upon the temperature, relative humidity, and motion of the air.

When the temperature and relative humidity are not too high, and when the body is not too active, the body gets rid of its excess heat by radiation, convection, and conduction. When engaged in work or exercise, the body develops much more internal heat, and perspiration begins. Perspiration rapidly evaporates if the relative humidity is low. If, however, the relative humidity of the air is high, the moisture cannot evaporate, or does so only at a slow rate. In such cases, the excess heat cannot be removed by evaporation, and discomfort follows.

The amount of heat given off by the body varies according to the body's activity. When seated at rest, the average adult

male gives off about 380 Btu per hour. On a ship, a man gives off an average of 500 to 600 Btu per hour.

Research has shown that the total amount of heat loss is divided as follows for light work on a ship (particularly on a submarine) : About 45 percent by radiation, 30 percent by convection and conduction, and 25 percent by evaporation. For normal body comfort, it is important that the heat loss be in these proportions.

If a person loses the same total of heat in the proportions of 40 percent by radiation, 50 percent by convection and conduction, and 10 percent by evaporation, he feels uncomfortable, damp, and chilly. This represents a condition of high relative humidity and too much air motion (a breeze from a fan or a direct draft). On the other hand, if the total heat loss is the same, but divided in the proportion of 30 percent by radiation, 25 percent by convection and conduction, and 45 percent by evaporation, a person will feel uncomfortable, hot, and parched. This represents a condition of low relative humidity and no air motion.

It is apparent that while the total heat loss may be a desirable amount, it may be given off so as to produce distinct discomfort. It is essential that the air conditioning be so controlled as to enable these heat losses to occur in the best proportions to produce comfort.

## SENSATION OF COMFORT

From the foregoing discussion it is evident that the three factors—temperature, humidity, and air motion—are closely interrelated in their effects upon comfort and health. In fact, a given combination of temperature, humidity, and air motion will produce the same feeling of warmth or coolness as a higher or lower temperature in conjunction with a compensating humidity, and air motion. It is the net effect of these factors, then, in which we are interested. The term given to this net effect is EFFECTIVE TEMPERATURE. This temperature cannot be measured by any instrument, but may be found on a special psychrometric chart when the dry-bulb and wet-bulb temperatures and air velocity are known.

Though all the combinations of temperature, relative humidity, and air motion of a particular effective temperature may produce the same feeling of warmth or coolness, they are not all equally comfortable. It has been found that a relative humidity below 15 percent produces a parched condition of the mucous membrane of the mouth, nose, and lungs, and increases susceptibility to disease germs. A relative humidity above 70 percent causes an accumulation of moisture in clothing. For best health conditions, relative humidity of from 40 to 50 percent for cold weather, and from 50 to 60 percent for warm weather, is desirable. An over-all range from 30 to 70 percent is acceptable.

There is also an optimum range of air velocity. This range varies from approximately 15 to 20 fpm to about 100 fpm. In general, if an air current is definitely perceptible—that is, if it attracts attention—then it is too much for comfort and may be a hazard to health.

A Comfort Chart, constructed to indicate the ranges of temperatures, relative humidities, and air velocities which produce a normal feeling of comfort for most persons, is illustrated in figure 12–2. This chart is for air velocities of from 15 to 25 fpm. You will note that the range of acceptable conditions for winter is different from the range for summer.

## AIR CONDITIONING SYSTEMS

The first air conditioning systems installed aboard ship covered only one or two spaces. These were vital spaces, ready rooms aboard carriers, magazines, CIC, or main plotting station. The Freon–12 plant was used.

Present air conditioning installations of combatant vessels cover practically the entire ship except for the machinery spaces. Besides all vital spaces, berthing, living, and office spaces are air conditioned.

### Basic Air Conditioning Cycle

A space gains heat from personnel and equipment inside the space and from heat transmitted through the metal decks and bulkheads. Moisture is added by personnel and any

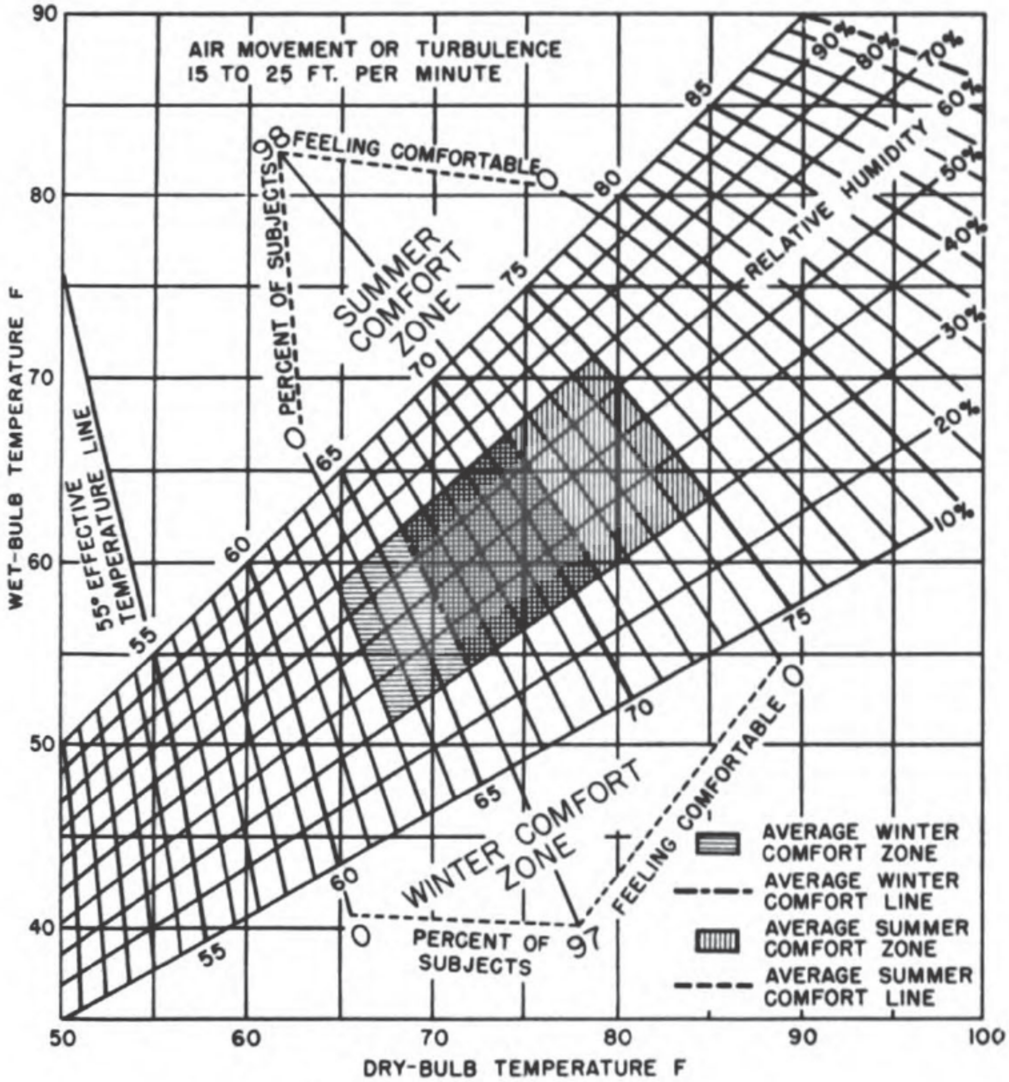



**Figure 12–2.—Comfort chart.**

sources of water that may be present in the compartment.

Starting from the space to be cooled, the air conditioning cycle (see fig. 12–3) is as follows: The hot, moist air from the space is drawn through a duct, where it mixes with fresh air drawn in from the outside. (There is no bypass factor on SUBMERGED submarines.) The fan blows the air over the cooling coil, and the refrigerant inside the coil cools the surface of the coil. These cold surfaces absorb the heat in the air passing over them and condense the excess moisture. The moisture drips off into a pan below the coil and is carried away by piping. The cool, dry air leaving the coil is blown into the compartment to be air conditioned, where it absorbs

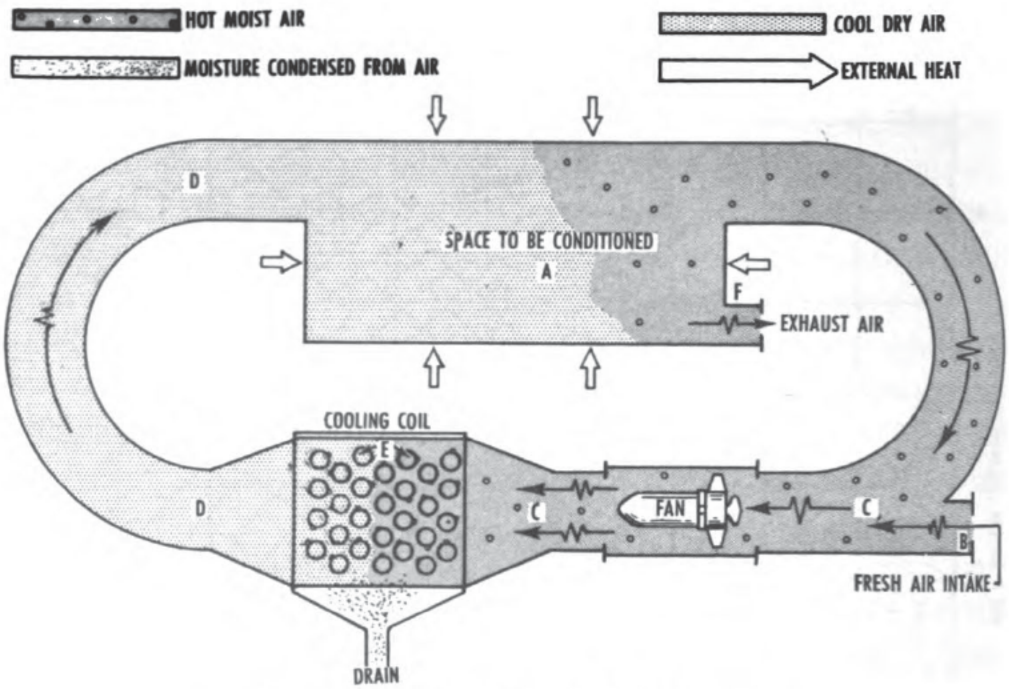



Figure 12–3.—Basic air conditioning cycle.

the excess heat and moisture in the space, and is then returned to the cooling coil. Air is exhausted from the space in order to allow for fresh air being drawn into the space.

## Shipboard Air Conditioning Cycle

The cooling coils are installed in the ventilation ducts leading to the spaces to be air conditioned. Automatic and manual controls are added to regulate the operations of the air conditioning equipment.

The vital spaces have recirculating units in the compartments operable during general quarters. When compartments have been shut and ventilation systems secured, a satisfactory supply of oxygen is maintained by blowing through these compartments with fresh air at least every 4 hours, or at the discretion of the damage control officer.

On large ships completely equipped with air conditioning, the installation is divided into a number of systems. Some ships have 6 systems, divided into 3 "hotel" systems and 3 vital systems. The ship is divided into 3 zones—forward, midships, and aft—with 1 hotel system for each zone. Chilled water is used as a refrigerant medium.

## AIR CONDITIONING PLANTS USED BY THE NAVY

The primary function of an air conditioning plant is to remove the heat from a compartment and discharge it overboard. The removal of heat results not only in lowering the temperature but also in dehumidification. In some types of plants the heat is picked up from the compartment by means of a chilled water system. This heat is transferred from the chilled water to the salt water, which is pumped overboard. This transfer of heat cannot be accomplished by the conventional heat exchanger; therefore, other methods and equipment must be used.

At present there are several types of air conditioning plants used by the Navy, design and construction depending upon the characteristics of the refrigerant used. These plants are in an experimental status to determine which type is best suited to naval use. Steam jet, lithium bromide, and Freon–12 plants have been installed on naval vessels.

### Steam Jet Plant

The steam jet plant, classified as a thermocompression plant, operates on the principle of cooling water by evaporation. Except for a few pumps, this type of cooler has no moving parts. The major parts of this plant are the flash tank, the booster ejector, the condenser, and the air ejector. (See fig. 12–4.)

Water from the chilled water system is continuously sprayed into the cold flash tank through nozzles in the spray pipes. The pump keeps the water in circulation throughout the chilled water system and returns it to the flash tank or evaporator.

Upon entering the flash tank, which is under a very high vacuum, a small part of the sprayed water flashes into vapor and by this action absorbs heat from the remaining water. It is necessary to flash only a very small portion of the water to produce the desired cooling effect.

The flashed vapor is removed from the flash tank by the

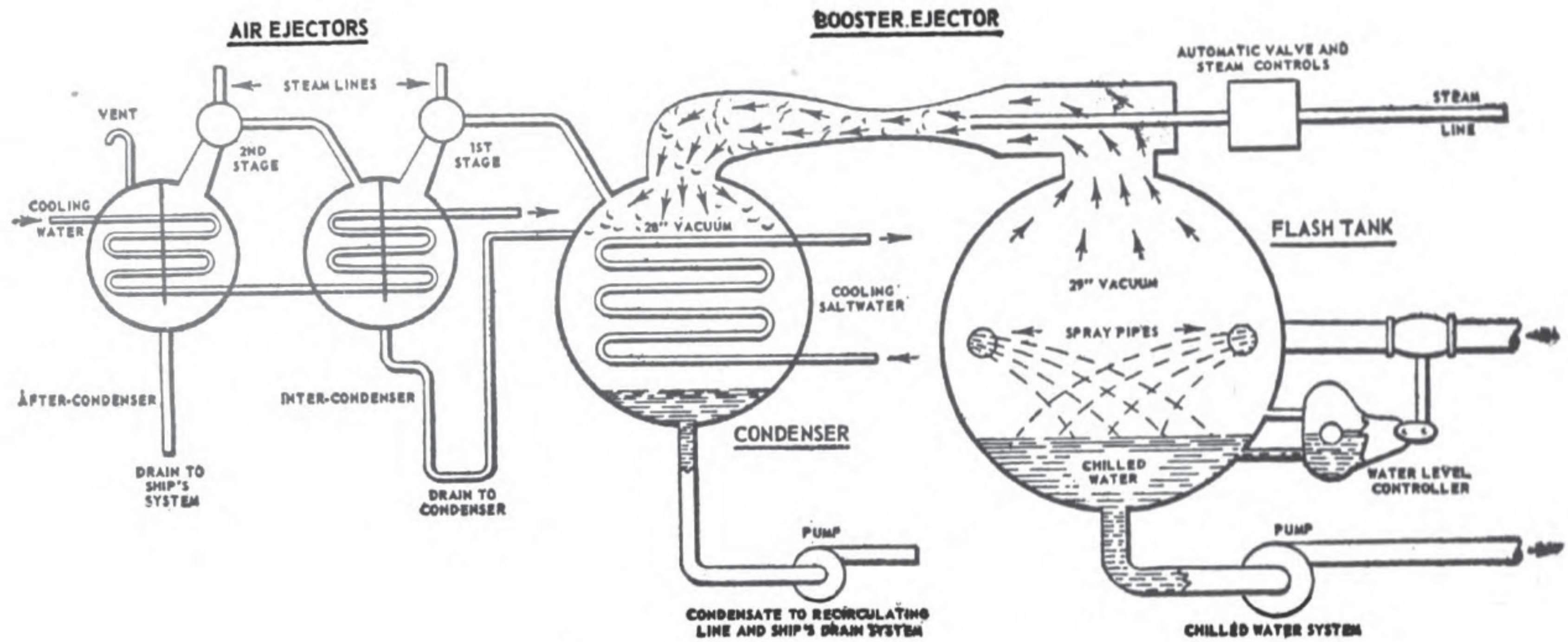



Figure 12–4.—Schematic drawing of the steam jet plant.

booster ejector and sent to the condenser. The booster ejector is supplied with steam and works on the same principle as an air ejector in maintaining a vacuum in the flash tank.

The condenser and the air ejector work on the same principle as similar units found on a steam-driven ship. The vapor and steam from the booster ejector are condensed, and the condensate is returned to the ship's steam heating drain system. The air ejector, which is of the conventional two-stage design, maintains a vacuum on the condenser.

The steam jet plant is designed for automatic operation after the necessary starting operations have been completed. During light loads the booster ejector will function in an on-off cycle, and the other component parts will operate continuously. To prevent the system from freezing on light loads, the booster ejector steam supply is controlled by an automatic valve.

### Lithium Bromide Plant

The lithium bromide plant operates on the principle of the absorption cycle. It is a steam-operated water-cooling plant, employing chilled water as the refrigerant and a solution of lithium bromide as the absorbent. Lithium bromide is a desiccant that is capable of absorbing water.

The major parts of the plant are two shell units, a heat interchanger, an eductor, and pumps. One unit contains the evaporator and the absorber; the other unit contains the generator and the condenser. (See fig. 12–5.)

The evaporator consists primarily of a spray pipe and a water tank or receiver. The incoming water is sprayed into the upper half of the shell. Chilled water which has not vaporized is collected by the receiver part and returned to the chilled water system by means of a pump.

The absorber unit consists of a lithium bromide liquid solution spray pipe and sea-water cooling coils. Salt water is pumped through these coils to cool the absorbing lithium bromide. The liquid solution is collected in the bottom of the shell.

The generator consists primarily of a steam coil, located in the bottom half of the shell. Steam, supplied by the ship, is passed through the tube nest to boil the liquid lithium bromide in which the tubes are submersed.

The condenser unit consists of a cooling coil and a condensate receiver or drain tank. Salt water, which is piped from the absorber cooling coil, flows through the tube nest.

The heat interchanger, eductor, and pumps are of conventional design.

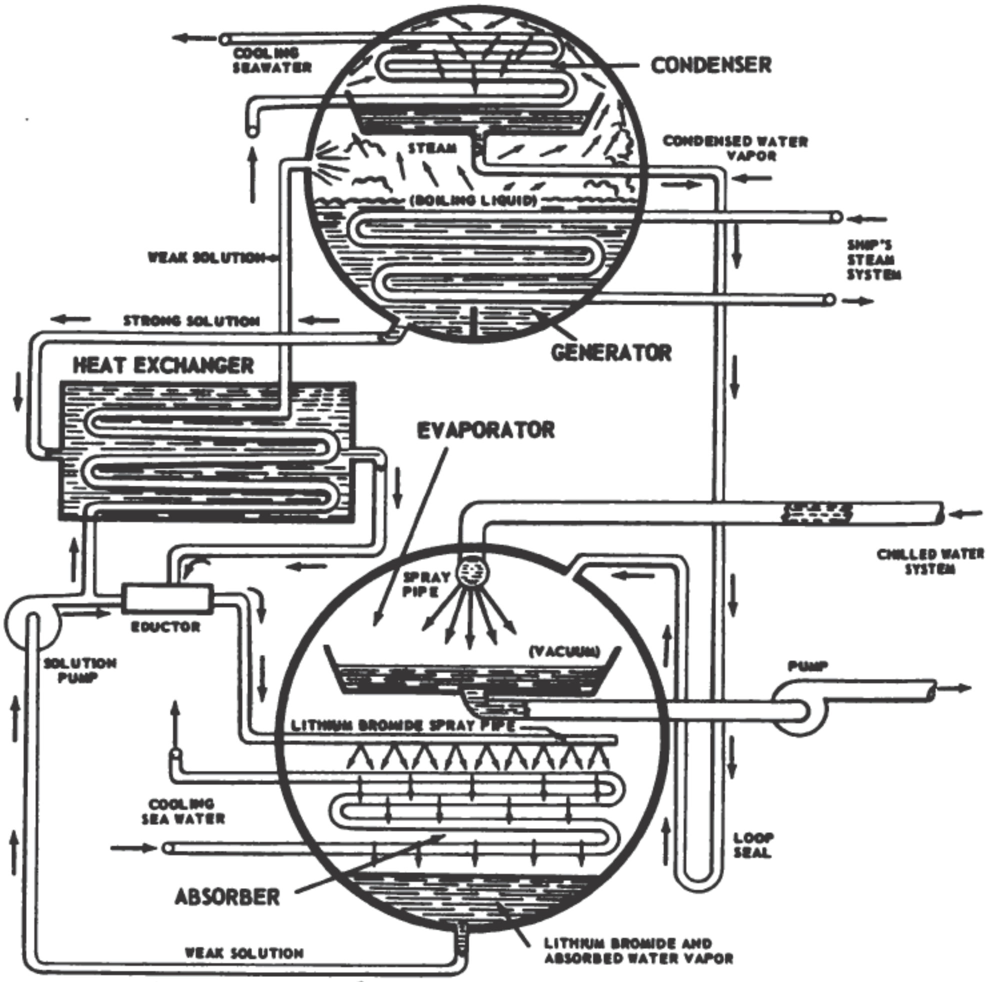



**Figure 12–5.—Schematic drawing of the lithium bromide plant.**

In the lithium bromide plant, chilled water is sprayed into a chamber within the evaporator in much the same manner as in the steam jet plant. The shell being under vacuum causes a small part of the water to flash into a vapor, which cools the remaining water.

The vacuum in the shell is obtained by spraying a lithium bromide solution over the cooling coils of the absorber unit. The amount of vacuum maintained in the unit depends upon the concentration and temperature of the solution. This solution absorbs the water vapor flashed in the evaporator. The salt-water cooling coil functions to remove the heat of condensation of the water vapor, and the heat of absorption of the solution, from the shell. The proper operation of the shell unit, containing the evaporator and the absorber, depends upon a high vacuum, a strong concentration of the lithium bromide solution, and a low temperature of the solution and shell space.

The above process would very quickly result in the dilution of the lithium bromide solution with the absorbed water from the chilled water system—a dilution which would reduce the absorbing action of the solution. Therefore, the water must be removed in order to keep a concentrated solution. This removal is accomplished by continuously draining part of the liquid from the primary lithium bromide solution system, and sending this liquid to the generator, where the diluted or weak solution is boiled to remove the excess water. Steam coils are used to heat the liquid in the lower part of the generator shell.

The steam from the boiling liquid is condensed in the upper part of this shell. Salt water is circulated through the condenser to cool the steam and transform it back into water, which is then returned to the evaporator section. The concentrated lithium bromide is returned to the primary circulating system. The loop seal maintains a difference of pressures between the two shells.

The heat interchanger is added to the plant to improve the efficiency and to reduce cooling water consumption. The hot, strong solution will transfer its heat to the cool, weak, solution which is to be boiled in the generator. The strong solution must be cooled to prevent it from carrying heat to the absorber unit.

Automatic devices and controls are added to operate or control the various piping systems. Relief valves, gages, and

thermometers are also included. A purge system, not shown in figure 12–5, is installed to remove air and noncondensable gases from the plant.

## Freon–12 Plant

The Freon–12 air conditioning plant is a refrigerating system using mechanical compression. The refrigerant cycle in this plant is the same as in the ship's main refrigeration plant. In general, the machinery, equipment, and piping arrangements of the two plants are similar.

COMPRESSORS. The Freon–12 reciprocating compressors are built in different sizes. The size of the compressor varies in accordance with the capacity required.

Operating suction pressures and evaporator temperatures used in the air conditioning system are higher than those used in refrigeration systems. This difference in suction pressure results in a corresponding effect on the rated capacity of the compressor. More refrigerated tons are developed at a higher suction pressure, and at a higher evaporator temperature.

It is not good practice to allow a Freon–12 compressor to remain idle for an extended period of time. Compressors should be operated at least once a week. Therefore, if a duplicate or standby compressor is furnished, it should be operated alternately with the main compressor, changing from one to the other at least every week.

THERMOSTATIC EXPANSION VALVE. In air conditioning installations the external equalizer is used with the thermostatic expansion valve, in place of the internal equalizer. The internal equalizing port between the valve outlet and the spring chamber is eliminated; instead, there is an opening through the valve directly into the spring chamber. By means of a copper tube the spring chamber is connected to the evaporator coil, beyond the point of greatest pressure drop. The external equalizer is used because in the air conditioning system there is a larger pressure drop between the two ends of the cooling coils than in the refrigeration system. This pressure drop is due to the fact that the tubing

used is smaller, and has restricted bends. Figure 12–6 illustrates the external equalizer type of expansion valve.

The thermostatic expansion valve should function without any difficulty if the system is free of foreign matter or moisture. Any foreign matter between the seat and the stem

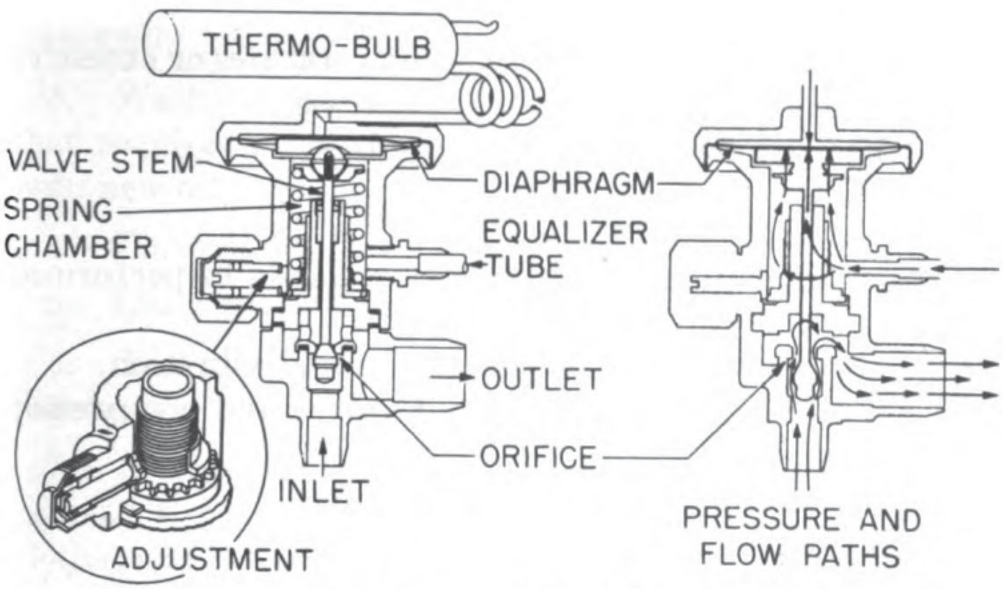



**Figure 12–6.—Thermostatic expansion valve, external equalizer.**

will prevent the value from closing tight. Presence of moisture in the system may cause a freeze-up at the port valve and block the passage of the refrigerant.

The system operates most satisfactorily when there is at least a 60-psi differential between the high-pressure and the low-pressure sides of the valve.

The thermosatic expansion valve is a delicate instrument, and should be handled carefully. If disassembly of the valve is necessary, follow the procedures specified in chapter 59 of BuShips *Manual*, or in the manufacturer's instruction book.

## INSPECTION SCHEDULES

To ensure proper operation of any Freon–12 air conditioning plant, periodic inspections must be made of compressors, valves, motors, coils, etc., and a check must be kept on temperatures.

### Daily Inspections

The following inspections should be performed daily:

1. Check all motors for overheating.
2. Check the oil level in the crankcases of the compressors every two hours.
3. Check for excessively high and low refrigerant pressures.
4. Check the crankcases for low temperatures or excessive liquid Freon–12 returning to the crankcase.
5. Clean the grease filters in the galley.

### Weekly Inspections

Weekly inspections and maintenance should be performed as follows:

1. Check all fans for unusual noise and vibration.
2. Check all regularly operated valves and compressor seals for leaks.
3. Check V-belts for proper tension.
4. Check the flywheels and pulleys.
5. Clean the evaporator coils which are not protected by filters.
6. Clean and dust all equipment.
7. Clean the air filters.

### Monthly Inspections

Every month, a check of the system should be made, as follows:

1. Check the V-belts for wear, and clean off all oil and dirt.
2. Check all systems carefully for refrigerant leaks.
3. Check and clean all automatic control and safety devices, also all switch contacts.
4. Check and clean the condenser tubes when refrigerant or water temperatures indicate the need.
5. Inspect the evaporator coils; clean them at least every 3 months, and more often if necessary.
6. Inspect the zinc fingers in the condensers; replace the zinc when deterioration amounts to as much as 30 percent.

### Yearly Inspections

The following inspections should be made at least once a year:

1. Disassemble motors and inspect and clean the motor windings, as required.

2. Wash out motor bearings and refill them with new motor oil.

3. Wash out fan bearings, unless they are of the new type that requires no cleaning or oiling; check clearance; refill with new oil.

4. Check rusting of metal parts on all equipment.

5. Check all ball bearings; add grease when necessary.

6. Test all gages at least once each year, more often if necessary.

7. Inspect all insulation coverings of cold pipes, especially seams. Replace all rusted binding wires and rotted covering cloths; add seamfiller where necessary.

## SUMMARY

The primary function of air conditioning aboard ship is to keep personnel comfortable, alert, and physically fit at battle stations.

Temperature, humidity, and air motion are closely interrelated in their effects upon comfort and health. Though all the combinations of temperature, relative humidity, and air motion of a specific effective temperature may produce the same feeling of warmth or coolness, they are not all equally comfortable.

At present, the steam jet and lithium bromide types of air conditioning plants are in an experimental status. Since the Freon–12 plant is most commonly used, you will be concerned with its maintenance and inspections. The information given in the refrigeration chapter of this training course will be applicable to Freon–12 air conditioning plants.

## QUIZ

1. What is the primary purpose of air conditioning aboard ship?
2. What term is used to describe air which, at a given temperature, is holding the maximum amount of moisture?
3. What effect does a rise in air temperature have upon the air's capacity to hold moisture?
4. What is specific humidity?
5. Why is importance placed upon the control of relative humidity in air conditioning?
6. A mixture of dry air and water vapor contains what kind(s) of heat?
7. Within a compartment, when will the wet-bulb, dry-bulb and dew-point temperatures all be the same?
8. Given a dry-bulb temperature of 80° F and a dew-point temperature of 70° F, what will be the relative humidity of the air if the dry-bulb temperature is raised to 90° F?
9. The body gains heat by what means?
10. When does the heat convection loss occur within the body?
11. When a man is performing light work on a ship, how is the total amount of heat loss divided, for normal body comfort?
12. What term describes the net effect of the temperature, humidity, and air motion factors?
13. For best health conditions, what is the acceptable range limit of relative humidity during the summer?
14. What does a comfort chart indicate?
15. The steam jet plant operates on what principle?
16. What is the purpose of the booster ejector in the steam jet plant?
17. What air conditioning plant used aboard ship operates on the principle of the absorption cycle?
18. The amount of vacuum maintained in the shell unit of a lithium bromide plant, containing the evaporator and absorber, is dependent upon what factors?
19. Why is a heat interchanger added to the lithium bromide plant?
20. The Freon–12 air conditioning plant is referred to as what kind of system?
21. How frequently should Freon–12 compressors be operated?
22. Why is an external equalizer used in the Freon–12 air conditioning plant, instead of the internal equalizer which is used in the Freon–12 refrigeration plant?

23. In order for the Freon–12 air conditioning plant to operate satisfactorily, the minimum pressure differential between the high- and low-pressure sides of the thermostatic expansion valve should be how many psi?
24. How frequently should the oil level in the crankcases of the Freon–12 compressors be checked?
25. How frequently should compressor seals be checked for leaks?

# CHAPTER 13

## PIPING SYSTEM REPAIR AND MAINTENANCE

Reasonable care must be given the various piping assemblies as well as the units connected by the piping. Unless the piping system is in good condition, the connected units of equipment cannot be operated efficiently and the safety of the ship's personnel may be imperiled. Therefore, you should be familiar with the recommended procedures and safety precautions for piping systems.

### Care of Piping Systems in General

The most important factor in maintaining piping systems in satisfactory condition is keeping joints, valves, and cocks tight. To ensure this, it is necessary to make frequent inspections of the lines.

When a ship is in operative status, quarterly tests should be made on the main and auxiliary feed systems and on all salt-water piping. These tests must be conducted under full working pressure, and must be carried on for a period of time long enough to disclose any leaks or other defects in the system.

On ships in reserve or inoperative status, piping systems are never put under pressure for testing purposes only. However, care must be taken to see that piping not in use is kept thoroughly drained.

Piping should never be used for securing chain falls, for supporting weights, or as hand or foot holds.

Where piping passes through decks or bulkheads, and there is a possibility of movement of one with respect to the other, expansion bends or other offsets are usually provided to take up the movement. (Sometimes stuffing boxes or flexible bulkhead and deck connections are used.) Similar provisions must be made when new piping is installed. Stuffing boxes, when used, should be examined and set up before air tests of compartments are made.

Where instruction books are available for piping systems and associated equipment, they should be followed. However, if the instructions conflict with those in BuShips *Manual*, the Bureau should be consulted.

### Painting of Piping

External corrosion of piping is caused by not keeping the exterior surfaces properly painted and free of moisture. Graphite or asphaltum paint makes an excellent preservative for exterior piping surfaces. Piping in bilges, voids, and ballast tanks should not be painted unless it is of steel or iron, unprotected by galvanizing. Copper and brass pipe should never be painted.

### Identification Markings

In addition to the regular painting all the piping throughout the ship must be stenciled, in letters 1¼ inches high, with the name of the service and destination. On pipe sizes smaller than 1 inch, identifying stencils ¾ inch high may be used. Arrows 3 inches long indicating the direction of flow should be painted near the stenciled lettering. Arrowheads should point in the direction of the flow; where the flow is reversible, there should be arrowheads pointing in both directions.

Designations applied to piping should be in conspicuous locations, preferably near control valves, and at suitable intervals so that every line has at least one identification in each compartment through which it passes. The piping should be painted the same color as the compartment through which it passes.

Continual leakage at a joint where a branch line joins another line is generally due to improper alignment. When joints are out of line, the pipe should be realigned, so that flanges, screw threads, and unions meet properly without forcing. A slight alteration in the anchorages, connections, hangers, or piping leads, to allow the required expansion and prevent strain, or the fitting of supports which will prevent vibration, will often be sufficient to correct leaky joints. On some flange joints it may be necessary to reface the flanges or to fit distance pieces. Small leaks in gaskets should be checked immediately, since a dangerous blowout may result from progressive growth of the leak.

PERMANENT REPAIRS. Small holes may be plugged with a rivet or a screw. Soft solder patches are seldom permanent, especially on piping subject to expansion and contraction, or to vibration.

To make permanent repairs on sections of leaky copper or brass tubing, the piping should be removed and the defect closed by brazing.

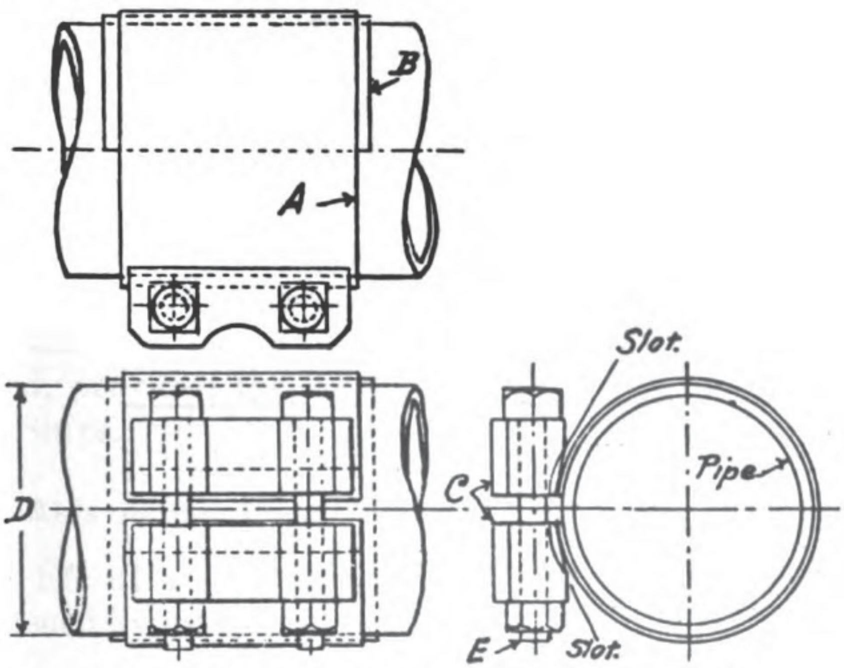
SEMIPERMANENT REPAIRS. These are generally made by serving the piping with tightly drawn wire, soldered or brazed as it is applied. Several layers of wire securely bonded give a strong, tight repair.

TEMPORARY REPAIRS. Repairs of a temporary nature can be made by securing a patch over the leak. The material used for the patch depends on the purpose for which the piping is used. It is considered good practice to make the patch from the same material as is used for flange gaskets of the piping. Back up the patch with a piece of sheet metal and secure with metal bands.

For low-pressure salt-water piping, red lead putty wrapped with canvas and served with marlin or electric friction tape makes a satisfactory patch. A small leak in salt-water piping can be stopped by driving in a soft pine plug. The moisture will cause the wood to swell and remain in place.

Portland cement patches can be cast in place and secured by the band method, or they can be cast entirely around a low-pressure water line. Iron cement can be used effectively on iron or steel piping carrying low pressure.

To remedy a defect in practically any size piping, a universal soft patch device, illustrated in figure 13-1, can be applied. This device has been tested on piping of various hole sizes, and has satisfactorily withstood pressures from 100 to 300 psi.




**Soft patch for emergency repair of leaky piping.**

***NOTES***

1. **Item A to be 20- or 22-gage steel metal.**
2. **Item B to be sheet rubber one-eighth inch thick.**
3. **Item C to be steel or composition. One set adaptable to nearly any size piping (slotted for item A).**
4. **Diameter D of piping need not be fixed since by changing item A, any size of piping may be accommodated.**
5. **Clamping bolts are one-half inch in diameter.**

**Figure 13–1.—Soft patch device.**

Emergency repair clamps similar to those shown in figure 13-1 and emergency couplings can be found in repair lockers. If no emergency repair clamps are available, they can be readily made.

## Insulation of Piping

Copper, copper-nickel alloy, and brass piping in bilges must not rest in contact with the iron or steel components of the ship. All securing brackets and hangers for this piping should be lined with sheet lead or with some other soft metal, to prevent hardening of the piping or squeezing when tightening up on the brackets.

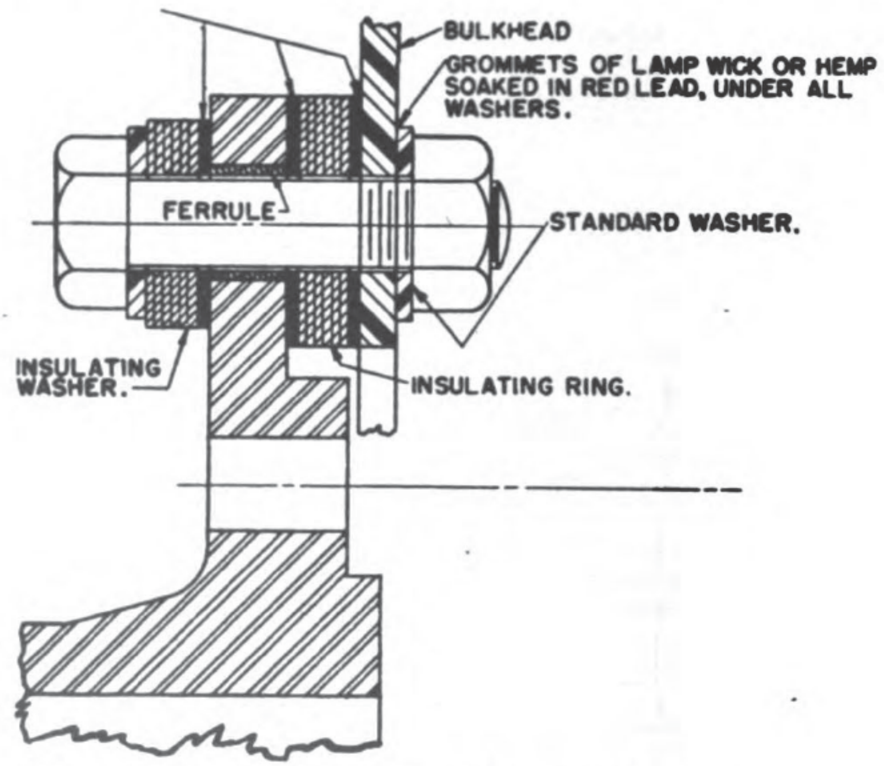



Figure 13–2.—Insulation of bulkhead flange.

Bulkhead flanges for all steam piping should be insulated to prevent the transfer of heat to the bulkhead. The flanges should also be insulated from the bulkhead (see fig. 13–2) with an approved heat-resisting material not affected by water and capable of sustaining, without crushing or injury, the compression produced by the bolts to secure watertightness.

## SALT-WATER PIPING SYSTEMS

In salt-water piping employing the same material throughout the system, cast iron protective spools and zinc boxes are not necessary—in fact, they are not desirable.

In salt-water piping systems with ferrous piping and nonferrous valve(s) or fittings, cast iron spools would give adequate protection against galvanic corrosion. But because cast iron is vulnerable to shock, it is not satisfactory for service aboard naval vessels. A spool of copper or brass, with a steel or iron waste sleeve inserted, may be used. The waste sleeve gives the same protection from galvanic corrosion as would be obtained from the use of cast iron spools, and also provides a source of waste material which is not a strength member of the piping system.

### Renewal of Salt-Water Piping

In the renewal of nonferrous piping systems, copper-nickel alloy piping should be used. In ferrous or nonferrous piping systems, replacements should be made in kind, i. e., using the same materials and protective coatings as found in the remainder of the system. However, if excessive maintenance has been performed, copper-nickel alloy piping may be used, provided the substitution is specifically approved by BuShips.

### Aids in the Preservation of Salt-Water Piping

The life of all metals used in salt-water systems can be lengthened by performing the following:

1. Eliminate grounds from electrical systems, particularly d-c circuits.
2. Eliminate air from salt-water systems.
3. Operate with minimum water velocities practicable.
4. Eliminate leaks promptly.
5. Insulate with sheet rubber the hangers which support piping other than that made of wrought iron or steel.
6. Eliminate vibration or other sources of mechanical damage to piping.
7. Eliminate wire-drawing by fully opening valves where throttling is not necessary.
8. See that the electrical insulation effect of rubber-lined spools is maintained in ferrous piping systems. This can be

accomplished best by completely eliminating leaks, painting the flanges with insulating varnish, and covering the flanges with cloth to prevent sweating.

9. Avoid subjecting piping with protective coatings (galvanized, tinned, solder-wiped) to heat which would cause local destruction of coating and promote galvanic action.

## VALVES

Valves as well as other units of equipment require proper care and maintenance. Valve troubles should be corrected as soon as possible.

### Causes and Remedies of Valve Leakage

Valve leakage is generally a result of the disk and the seat failing to make a tight joint, and this failure may be due to one of the following causes:

1. Foreign substances (scale, dirt, waste, or heavy grease) are lodged on the seat in such a way that the disk cannot be seated. If the obstructing material cannot be blown through, the valve will have to be opened and cleaned out.

2. Scoring of the seat or disk has been caused by attempts to close the valve on scale or dirt, or by corrosion. If the damage is slight, the valve may be made tight by grinding the disk together with the seat; if the damage is extensive, a cut will have to be made on the disk, and the valve seat ring may have to be renewed before it is ground.

3. The disk may not seat properly because of a bent spindle guide, or a bent valve stem.

4. The valve body or disk may be too weak for the purpose for which it is used, causing distortion of the valve seat or disk under pressure.

5. In bronze valves fitted with seat rings, leakage through the valve may occur as the result of leakage around the threads of the seat rings. To correct this defect, remove the seat ring, clean the threads, and remake the joint. It may be necessary to recut the threads in the valve and to renew the seat ring to secure tightness.

LOOSE VALVE DISK. When a valve disk comes loose from its stem, the cause is either failure of the securing device or

corrosion through the stem. The first cause is infrequent in valves of good construction, and recurrence can be prevented by minor adjustments or by greater care in reassembling valve parts. Corrosion of the valve stems occurs mostly to valves installed in salt-water lines. Stems which have shown signs of corrosion should be inspected periodically so that replacement can be made before failure occurs. Replacements should be made with rolled monel-metal stems. In order to prevent failure caused by corrosion, split pins in valve disks in the water lines should be of nickel-copper alloy instead of iron, steel, or brass.

Refacing, Grinding, and Spotting. If the seat and disk of a valve are scored badly, they should be refaced either in a lathe or with a reseating tool. Following the refacing, the seat and disk are ground together with an abrasive such as grinding compound, or powdered emery.

Grinding may be difficult with heavy valves which are placed upside down or at an angle. In such cases it is best to use a jig to guide and support the disk, otherwise it will be almost impossible to obtain satisfactory results. Some valves when ground cold will not be tight when heated; the only solution is to grind the valve while hot. Heating can be accomplished either with a torch or by keeping a ring of red-hot metal in contact with the disk.

In several cases, the use of high temperature high-pressure steam has resulted in serious wear and erosion of the valve parts, such as seat rings and disks, exposed to the steam. To prolong the life of these parts a process of surfacing by welding with a suitable heat-resisting alloy (such as cobalt-chromium to specification 46R5 or an approved alternate alloy) is recommended. An advantage of this process is that damaged weld metal can be removed by grinding and new material can be applied, thus retaining the original valve parts in service for a considerable time, and eliminating the expense and time required to manufacture entirely new valve parts. Minor defects may be removed by grinding to the extent of the thickness of the original welded surface. However, grinding of one welded surface against another

does not produce the most satisfactory seating surface and, therefore, should be avoided. The valve disk may be removed by grinding by machine tools; however, if it is impracticable to remove the valve body, grinding of the seat ring should be accomplished by using grinding compound and a cast-iron dummy disk machined to the angle required. In some cases this angle may differ 1° or 2° from that of the disk. Detailed drawings of the valve should be referred to for this information. The dummy disk will require occasional machining to retain its proper angle and remove overlapping shoulders, which cause iregularities.

### Inspection of Sea Valves in Drydock

When a ship is in drydock, the engineer officer should see that all outboard valves are inspected and entries made in the engineering log. The inspection must include the following: yoke, yoke rods, securing bolts, and internal valve parts (stem, disk, disk securing device, tightness of valve, and the threads of the valve stems of the main injection and overboard discharge gate valves).

On each outboard valve, at least two of the bolts holding the valve to the sea stool should be removed and inspected. The other bolts should be sounded with a hammer. If any bolt is defective, all the bolts of that valve must be removed for inspection. In addition, the gaskets should be inspected, and renewed if necessary.

When sea gate valves are assembled, the gate should be in the half-open position before the bonnet bolts are tightened. This ensures that the guides in the valve bonnet align properly with the guides in the valve body.

### Installation of Valves

It is best to install a valve with the stem pointing straight upward. When the stem points downward, the bonnet acts as a pocket for scale or other foreign matter in the line. Such foreign matter may interfere with the valve operation by cutting and eventually destroying the inside stem threads. The recommended position for double-disk gate valves is with the stem upright; the spreader mechanism in the disk

may jam if the valve is installed in any other position. If the valve MUST be installed with the stem in a horizontal position, a one-piece wedge disk valve is preferred.

In liquid lines subject to freezing temperatures, the upside-down position for valves is undesirable, because liquid trapped in the bonnet may freeze and rupture the valve. As a precaution against freezing, valves in such lines, even when installed upright, should have drain plugs in the body.

GLOBE VALVES. Where the flow should be continuous, and where no harm could result from the valve being open because of a detached disk, the pressure from below the disk is advisable. This condition is best illustrated in the case of the disk of a globe valve in a boiler feed line which should have continuous flow. Pressure from above the disk might cause it to seat and check the flow.

If damage would result from a disengaged disk being blown open and leaving the globe valve wide open, it is best to have pressure from above the disk. This may be illustrated in the case of a valve used to regulate the flow of steam to a steam-driven pump. Should the disk become detached, the pressure from below might push the valve wide open and cause the pump to run wild. Here pressure from above the disk, as illustrated in figure 13–3, would be safer than pressure under the disk.

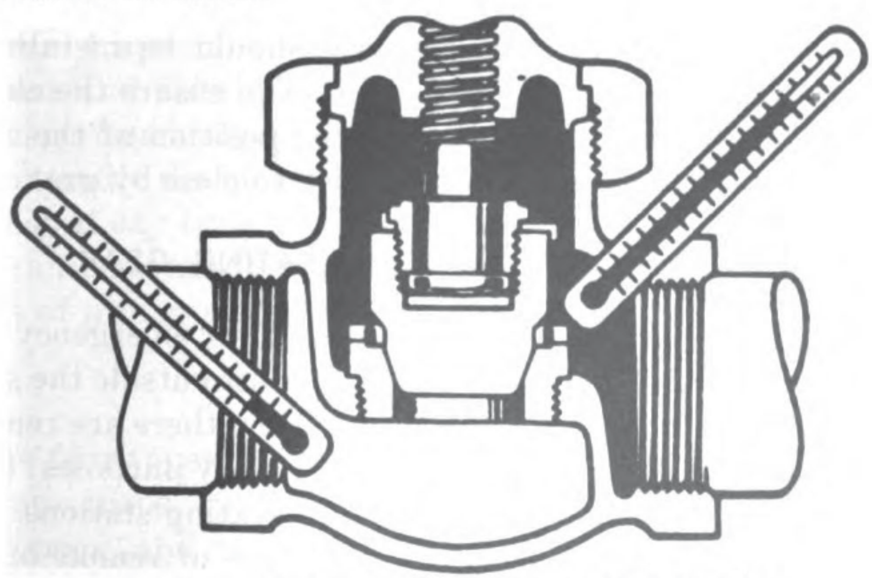


**Figure 13–3.—Pressure and temperature above the disk.**

Consider what may happen to a valve used for high-temperature service, if the pressure is under the disk. When the flow is shut off, the upper part of the valve is likely to cool. Cooling of the stem (see fig. 13–4) may cause sufficient contraction to unseat the valve just enough to cause leakage. The resulting extremely high rate of flow may cause severe erosion of the disk and seat. In this case, pressure from above the disk would be better than pressure under the disk.

Unless pressure under the disk is definitely required, a globe valve will generally give more satisfactory service when installed with pressure above the disk.

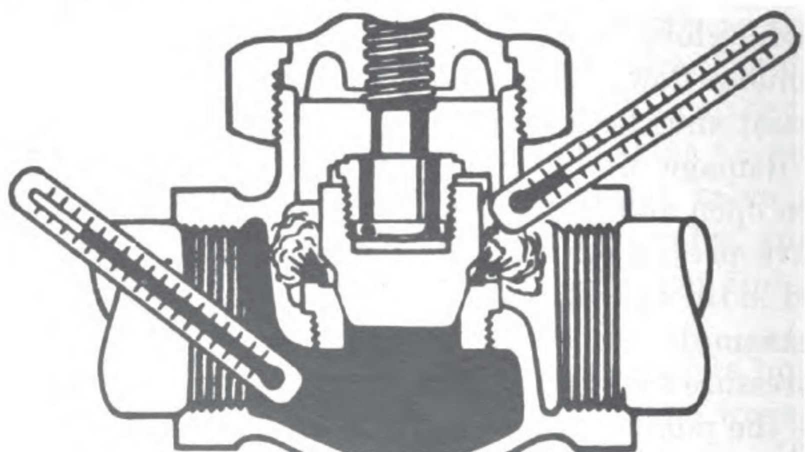


Figure 13–4.—Pressure under the disk.

CHECK VALVES. All check valves should be installed so that the disk will open with the flow. To ensure the closing of the disk when back flow occurs, the position of the check valves in the line must permit the disk to close by gravity.

## MECHANICAL REMOTE OPERATING GEAR

Remote-control operating mechanisms for emergency purposes are installed at various control points outside the space where the valves are located. In addition, there are remote-control mechanisms for other than emergency purposes; these mechanisms are generally located at operating stations. On board ship, there are generally three types of remote operation: (1) manual, (2) hydraulic, and (3) pneumatic.

Remote operating gear is installed to permit operation of valves from remote control points when the compartments within which the valves are installed are untenable. For this reason it is imperative that these valves and their operating gear be kept in the best possible mechanical condition.

All remote operating gear should be lubricated and valves operated through their full travel from remote control points at least once each week. This inspection, if not already included, should be incorporated in the weekly test and inspection sheet.

Flood valve and steam smothering system control valve operating gear should be inspected in accordance with specific instructions.

Steam smothering system control valve operating gear should be operated through the full valve travel at the same time that the steam smothering system is undergoing its periodic test.

If the remote control gear jams as a result of structural damage, an immediate inspection should be made of the installation, to determine the advisability of disconnecting the gear at the valve. Any deficiencies located during this inspection should be corrected as soon as possible.

## STEAM TRAPS AND DRAINS

Steam traps must be located below the lowest point to be drained and should be placed so as to be easily accessible for inspection and repair. A trap must have sufficient capacity to handle the maximum quantity of condensate that will reach it at any time. A trap that has been functioning properly can be overloaded if additional drains are led to it as a result of piping alterations.

### Types of Traps

The four types of traps used on naval ships are: (1) thermostatic traps, (2) ball-float or open-bucket traps, (3) impulse traps, and (4) continuous flow traps (without moving parts).

THERMOSTATIC TRAPS. These are light-weight types of traps of compact design. The discharge through the thermostatic trap is controlled by expansion of vapor from a volatile liquid enclosed in a bellows-type element. These traps are primarily used for draining heating systems and auxiliary exhaust drain lines. Use is limited to pressures under 100 psi gage. Inasmuch as this type trap requires a temperature differential of 10° to 30° F, a length of pipe is required for cooling, between the unit drained and the trap.

BALL-FLOAT OR OPEN-BUCKET TRAPS. Compared with the thermostatic or pulsating types, these traps are larger, weigh more, and have additional working parts. The ball-float trap is occasionally used where the working pressures do not exceed 100 psi. The inverted bucket traps are suitable for all services and pressures.

IMPULSE TRAPS. These traps are suitable for all services where the discharge pressure is not more than 25 percent of the line pressure. They are very compact but have a definite steam leak when the condensate increases.

CONTINUOUS FLOW TRAPS (WITHOUT MOVING PARTS). These traps are suitable where condensate formation is continuous and relatively constant. With a large reduction in condensate, the steam leakage may be too great for the system. These traps should not be used where slugs of water are developed.

### Inefficient Operation of Traps

The principal causes of faulty operation, and the remedies, are:

1. PUNCTURED FLOAT OR BUCKET. Remedy: Repair leak.
2. WORKING PARTS ADRIFT. Remedy: Secure the parts in place with additional securing devices to prevent repetition of the trouble.
3. VALVE DOES NOT SEAT PROPERLY:
   (a) Remedy: Use the hand tripping device, if provided, to dislodge any dirt or scale caught under the valve.
   (b) Remedy: Break the trap down and clean it.

4. Air-Bound. Remedy: Relieve by opening the air cock. When a cold trap is to be operated, leave the air valve open until steam or water issues from it.
5. Sediment in Bottom of Trap. This condition may prevent proper operation. Remedy: Blow out if possible; otherwise, break the trap down and clean it.
6. Open or Leaky Bypass Valves. Remedy: Close or tighten the valve.

### Inspection and Repair of Traps

All traps should be inspected quarterly and those found to be leaking should be repaired immediately. Leaky traps waste an enormous amount of steam.

Traps should be adjusted, if possible, so that steam is never discharged, as the passage of steam produces erosion. Trap valves and valve seats which have given trouble as a result of erosion should be replaced with valves and seats made of nickel-copper alloy, or of steel faced with chromium-cobalt alloy.

Traps should also be inspected to make sure that they comply with the following:

1. They should be located at the lowest point to be drained.

2. They should be placed where they are accessible for inspection and repair.

3. They should not be subjected to pressures higher than designed pressure.

4. They should not be subjected to a discharge head pressure of more than 1 foot of water for each 2 pounds of pressure within the trap.

Every trap other than thermostatic is normally fitted with a small atmospheric test valve installed in the discharge line between the trap and the trap discharge cut-out valve. To test the operation, close the discharge cut-out valve and open the test valve. The trap should then be tripped and it should be noted whether or not the trap shuts off properly. Some steam will accompany the discharged condensate because of reevaporation of a portion of the condensate at a temperature

of 212° F, and atmospheric pressure. However, a sizzle of steam after the trap shuts off indicates a leak. Impulse traps require about 3 percent of full condensate capacity to prevent the discharge of live steam. If the cut-out valve leaks, a false indication will be given when the drain line is under pressure from some other leaky trap. To determine the source of leakage, close the trap inlet valve. If the sizzle stops, the trap is leaking; if it continues, the discharge cut-out valve is leaking.

## Principal Drain Systems

All steam systems are drained through a closed system. On the newer ships, the main and auxiliary steam lines, including the 150-psi lines, are generally drained to the deaerating feed tanks by means of the impulse traps. For under way operation the pressure in the drain line for main and auxiliary steam lines is approximately 35 psi gage. Whistles and sirens, also drained by impulse traps, drain to the same tank, but through an independent line.

FRESH-WATER DRAIN COLLECTING SYSTEM. This system consists of atmospheric drains leading from the lowest point of all machinery parts where fresh water may collect and from which it is desirable to remove drainage when the machinery is not operating. All such drains should be fitted with drain valves and open sight-flow devices (funnels) arranged to prevent the entrance of foreign matter into the system. Any atmospheric drain from a closed fireroom discharging to this system should be fitted with a water seal (U-bend or equivalent) which will prevent leakage of air from the fireroom when the latter is under an air pressure up to 1¼ times the maximum specified for the particular ship.

SALT-WATER AND OTHER CONTAMINATED LEAKAGE DRAIN COLLECTING SYSTEM. This system is installed to collect salt-water drainage and oil leakage from machinery which normally operates with leakage; its purpose is to keep the bilges dry. The system carries this leakage to the bilge sump tank,

and it is then pumped to a contaminated oil tank, where the oil is allowed to settle out and the water remaining is pumped overboard.

## SAFETY PRECAUTIONS

The following safety precautions for piping systems should be observed:

1. Open bypasses, before opening large steam valves, to warm lines and equalize pressures. If bypasses are not fitted, crack the valves.
2. Open trap bypasses when admitting steam to the piping.
3. Conduct a quarterly hydrostatic test of the main and auxiliary feed piping and all salt-water piping.
4. Open drains during cold weather, to prevent freezing.
5. Do not use piping as handholds or footholds.
6. Exercise care in opening the steam blowing-out valve, to prevent a pressure in excess of 35 psi gage from building up in the sea chest.
7. Examine the bypasses and traps if the feed tank shows an abnormal rise in temperature.
8. Test the traps quarterly.

## SUMMARY

For efficient operation of equipment and to promote personnel safety aboard ship, the piping system must be maintained properly. If trouble arises, the piping connections in the vicinity of the trouble should be checked carefully and corrected as soon as possible.

Permanent repairs of copper or brass piping should be made by brazing. Semipermanent repairs of leaky piping sections may be made by serving the piping with tightly drawn wire, soldered or brazed as it is applied. Temporary repairs are generally made by securing a patch over the leak.

Faulty valve operation should be checked and corrected as soon as possible. When necessary, valves should be refaced and ground, spotted in, and installed properly.

When a steam trap does not operate efficiently, the trouble should be located and remedied, if possible, as recommended in BuShips *Manual* or in the manufacturer's instruction book.

Make certain that you are familiar with the general precautions concerning the application and maintenance of insulation. In addition, the safety precautions for piping systems, recommended by BuShips, should be observed.

## QUIZ

1. On ships in an operative status, how often should the main and auxiliary feed systems and all salt-water piping be tested?
2. What preservatives are recommended for exterior surfaces of piping?
3. If a small leak in a gasket of a piping joint is not remedied as soon as possible, what may be the result?
4. How should permanent repairs of copper or brass piping be made?
5. How should securing brackets and hangers for copper-nickel alloy and brass piping in bilges be lined?
6. When replacing nonferrous salt-water piping, what kind of piping should be used?
7. What should be done with a slightly scored valve seat?
8. Corrosion of valve stems occurs mostly to valves installed in which lines?
9. What should be done with a badly scored valve seat and disk?
10. When sea gate valves are assembled, why should the gate be in the half-open position before the bonnet bolts are tightened?
11. What is the best position in which to install a valve?
12. What determines the proper method for installing a globe valve?
13. How often should valves fitted with remote operating gear be lubricated and operated through their full travel from remote control points?
14. How should a steam trap be installed in a piping system?
15. How do ball-float traps differ from thermostatic or pulsating steam traps?
16. If a steam trap is not operating efficiently because the working parts are adrift, what should be done to remedy the trouble?
17. How often should steam traps be inspected?
18. What percentage of full condensate capacity is required by impulse traps to prevent the discharge of live steam?
19. On most recent vessels, what lines generally drain to the deaerating feed tanks by means of the impulse traps?
20. If the feed tank shows an abnormal rise in temperature, what should be examined?

# CHAPTER 14

# LATHE MACHINING OPERATIONS

## PRELIMINARY STEPS

Although machine shop work is generally done by men in other ratings, there may be times when you, as a Machinist's Mate, will find the use of a lathe essential in order to complete a repair job. Since you should already be familiar with the CONSTRUCTION of the lathe, only information relative to lathe operation is covered in this chapter. You should know the preliminary steps leading up to the performance of machine work with the lathe—how to mount the work and the tool, and what tools to use for various purposes. You should now be ready to take up the method of using the proper tools in combination with the lathe to turn, bore, and face the work to the form or shape desired, and to cut external and internal screw threads.

Before you begin manufacturing any piece, study the blueprint. Check over the dimensions and note the points or surfaces from which they are laid out. Make sure from the over-all dimensions that the stock you intend to use is large enough for the job. Plan the steps of your work in advance, in order to determine the best method of procedure.

Accuracy is the prime requisite of a good machine job; before you start, make sure that the centers are true and properly aligned, that the work is mounted properly, and that the cutting tools are correctly ground and sharpened.

For the purpose of instruction we will start with a job that

is to be machined on centers. Let us assume that we find, on testing, that the lathe centers are not true. It will be necessary then to make them true before proceeding with the work.

### Truing the Lathe Center

Lathe centers are usually too hard to be machined with a cutting tool and will require annealing. If annealing is necessary for truing a lathe center, you will probably request a replacement or submit a job order for the machining job. In most cases, you will use an ELECTRIC TOOL POST GRINDER, if available, to true up a lathe center.

To true a lathe center with a tool post grinder, remove the driving plate from the spindle. Before proceeding with the truing operation, examine the tapered hole in the spindle and see that all dirt and chips are removed. With a piece of rag on the end of a stick, thoroughly clean the tapered hole. Examine the shank of the lathe center and make sure that no chips are embedded in it and that all dirt is removed.

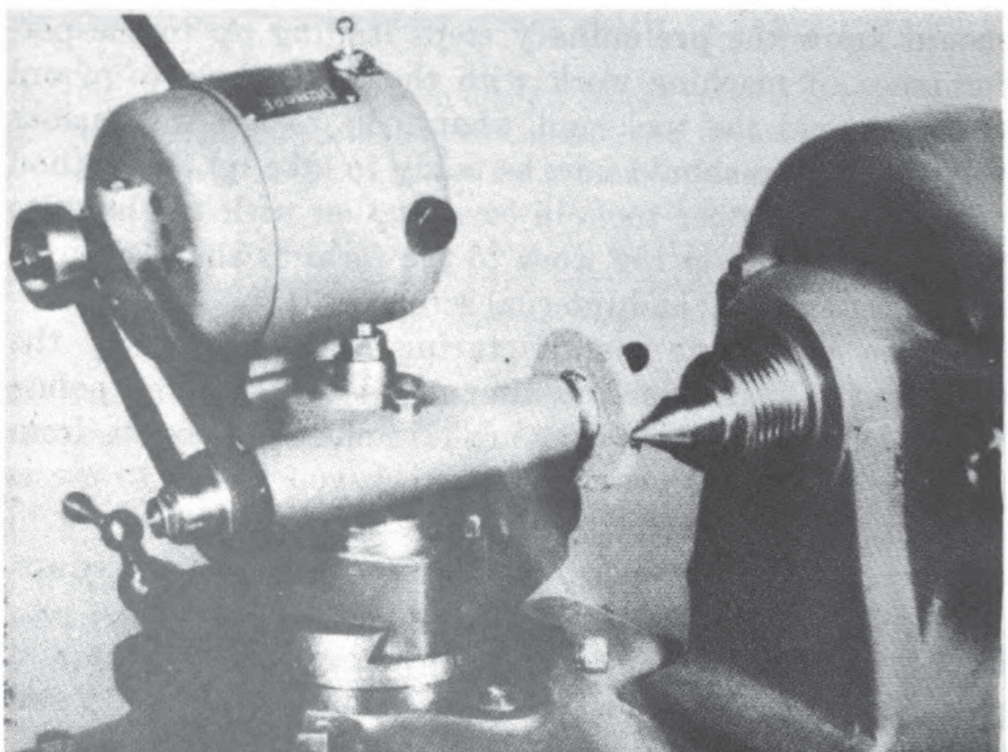


Figure 14–1.—Truing a lathe center with a tool post grinder.

FIRST, place the center firmly in the spindle, and set the compound rest at an angle of 30° with the axis of the lathe. SECOND, mount a tool post grinder or grinding attachment on the lathe, as shown in figure 14–1. THIRD, cover the exposed ways of the lathe with cloth or paper to prevent the grinding grit reaching the bearing surface of the bed and cross slides. FOURTH, put the headstock in gear to give approximately 200 rpm to the spindle, and with grinding wheel and center running in opposite directions, take a light cut over the center point, feeding the wheel across the point by means of the compound rest feed handle. (See fig. 14–1.) Continue to feed the wheel back and forth until it is cutting evenly all around, and on the entire length of, the center point, and then check the angle with a standard center gage Reset the compound rest if necessary and continue grinding until the center fits the center gage exactly. The accuracy of the fit can be observed by placing an electric-light bulb beneath the center and looking for light between the center point surface and the edge of the center point gage.

### Testing Center Alignment

For very accurate work, especially if the piece is long, the following test is necessary to correct any small errors in alignment not otherwise detected.

The work to be turned, or a piece of stock of similar length, is mounted on the centers. With a turning tool in the tool post, take a narrow cut to a depth of a few thousandths of an inch at the headstock end of the work. Then remove the work from the centers to allow the carriage to be run back to the tailstock without the tool being withdrawn. Do not touch the tool setting. Replace the work in the centers, and with the tool set at the previous depth take another narrow cut coming in from the tailstock end. With a micrometer caliper, compare the diameters over these cuts. If the diameters are exactly the same, the centers are in perfect alignment; if the diameters are different, the tailstock must be adjusted in the required direction by means of the set-over adjusting screws. Repeat the above test and adjustment

until a cut at each end produces equal diameters. The test, however, will be useless unless the lathe centers are true and accurate.

### Facing the Job on Centers

When accurate work is to be machined on centers, the first thing to do is to face the ends of the work. This is not only to get the ends square and clean, but also to machine the work to the proper length.

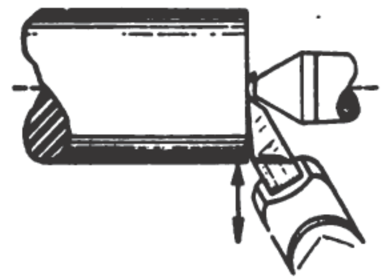


Figure 14–2.—Facing a shaft.

Figure 14–2 shows the method of facing a cylindrical piece. The work is placed on centers and driven by a lathe dog. A right-hand side tool is used, and a light cut is taken on the end of the work, feeding the tool (by hand cross-feed) from the center toward the outside. One or two cuts are taken to remove sufficient stock to true up the work. The dog is then placed on the other end of the work and faced to the proper length. A steel scale is used to measure off the length; another scale or straightedge held on the end that has just been faced provides an accurate base from which to measure. The desired dimension is marked off with a prick punch. Fins or burrs on the finished end will keep the straightedge from bearing accurately.

### Direction of Feed With Work on Centers

For machining a job on centers in the lathe, the feed of the tool should be, when possible, in the direction of the head spindle. The reason is obvious: When the carriage is feeding toward the head spindle and the tool taking a heavy chip, the pressure is on the head spindle center, which revolves with the work and hence does not wear. It is good practice to take as much load as possible off the DEAD center (tailstock center).

## PLAIN TURNING

Plain turning is the shaping of a piece of stock into a cylindrical surface.

### Rough Turning

When a great deal of stock is to be removed from the work, heavy cuts (rough turning) should be taken in order to finish the job in the least possible time.

A roughing tool should be selected for taking a heavy chip. The speed of the work, and the amount of feed of the tool, should be as great as the tool will stand.

When taking a roughing cut on steel or cast iron, or any metal that has a scale upon its surface, be sure to set the tool deep enough to get under the scale in the first cut, because unless you do, the scale on the metal will dull the point of the tool.

The work should be rough machined to almost the finished size; then care in measuring is required.

Remember that the diameter of the work being turned is reduced by an amount equal to twice the depth of the cut; thus if you desire to reduce the diameter of a piece by one-fourth of an inch, only one-eighth of an inch of metal must be removed from the surface.

Figure 14–3 shows the position of the turning tool taking a heavy chip on large work. The tool should be set so that if, during machining, anything occurs to change the position of

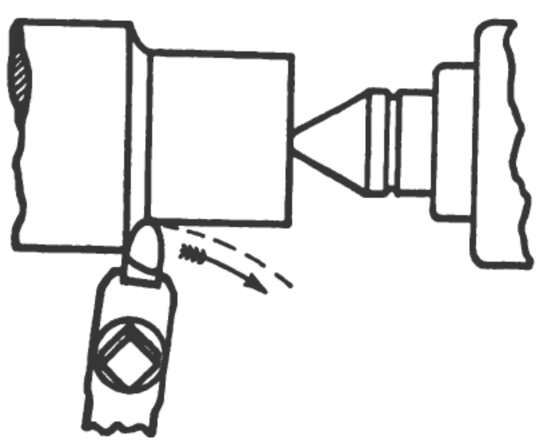


Figure 14–3.—Position of the turning tool taking a heavy cut on large work.

the tool, it will not dig into the work, but rather will move in the direction of the arrow—away from the work. Setting the tool in this position sometimes prevents chatter.

## Finish Turning

When the work has been rough turned to within about $\frac{1}{32}$ inch of the finished size, take a finishing cut. A fine feed, the proper lubricant, and above all a keen-edged tool are necessary to produce a smooth finish. Caliper carefully to be sure that you are machining the work to the proper dimension. Stop the lathe when measuring with calipers.

It is advisable to see that the work is not hot when the finish cut is taken, especially where very close limits are to be held. If the piece has been turned to the exact size, cooling would leave it undersized.

On work that is to be finished by a cylindrical grinder, a limited amount of stock is usually left for grinding to the finished dimensions.

Perhaps the most difficult operation in machine work is to make accurate measurements. So much depends on the accuracy of the work that you should make every effort to become proficient in the use of measuring instruments. A certain "feel" in the application of calipers is developed through experience alone; so do not be discouraged if your first efforts do not produce perfect results. Practice taking caliper measurements on pieces of known dimensions. You will acquire skill with persistent practice.

## Machining to a Shoulder

Machining to a shoulder is often done by locating the shoulder with a parting or cut-off tool. (See A of fig. 14-4.) The parting tool is inserted about $\frac{1}{32}$ inch back of the shoulder line, and penetrates the work to within $\frac{1}{32}$ inch of the smaller diameter of the work. Then the stock may be machined by heavy chips up to the shoulder thus made. Machining rough cuts to a shoulder eliminates the need for frequent measuring, and speeds up production.

In figure 14–4, B illustrates the method of shouldering. A parting tool has been used and the turning tool is taking a cut. It will be unnecessary to waste any time taking

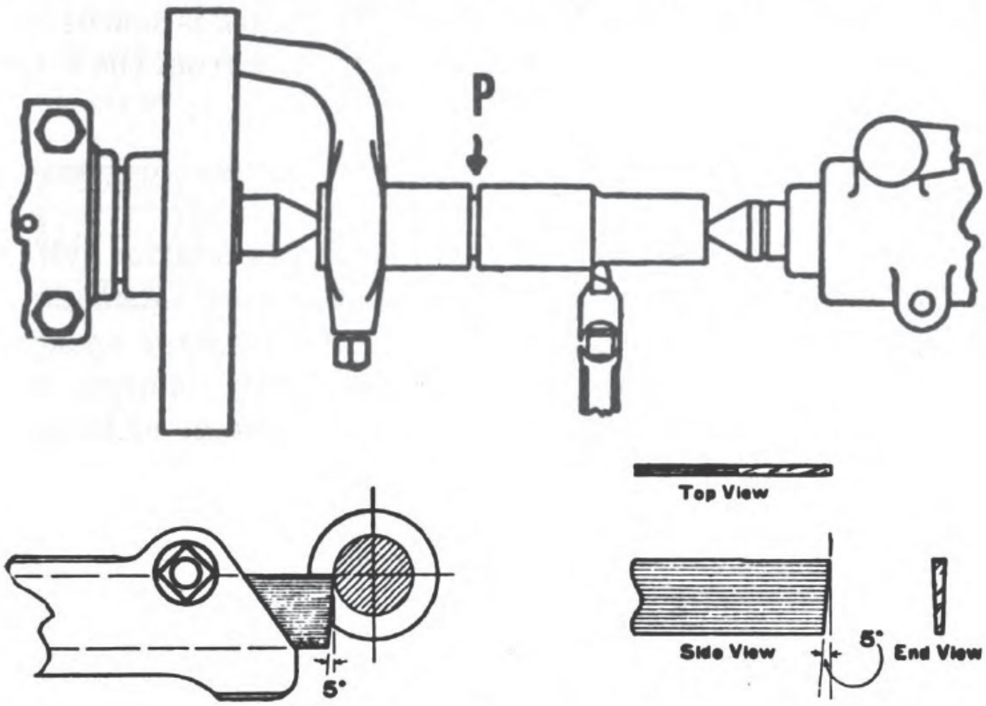



Figure 14–4.—Machining to a shoulder.

measurements. You can devote your time to rough machining until the necessary stock is removed. Then you can take a finishing cut to accurate measurement.

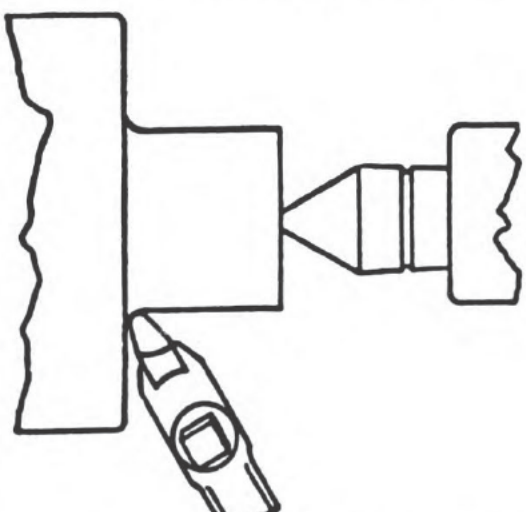


Figure 14–5.—Facing a shoulder with a fillet.

### Facing a Shoulder

Figure 14–5 shows the application of a turning tool in finishing a shouldered job having a fillet corner. A finish cut is taken on the small diameter. The fillet is machined with a light cut; then the tool is used to face from the fillet to the outside diameter of the work.

## BORING

Boring is the machining of holes or of any interior cylindrical surface. The piece to be bored must have a drilled or cored hole to start with, and the hole must be large enough to insert the tool. The boring process merely enlarges the hole to the desired size or shape. The advantage of boring is that the hole that is obtained is perfectly true; also, two or more holes of the same or different diameters may be bored at one setting, thus ensuring absolute alignment of the axis of the holes.

It is the usual practice to bore a hole to within a few thousandths of an inch of the desired size and then finish it with a reamer to the exact size.

Work to be bored may be held in a chuck, bolted to the faceplate, or bolted to the carriage. In the case of a long piece, the free end must be supported in a center rest.

When the boring tool is fed into the hole in work being rotated on a chuck or faceplate, the process is called single point boring. It is the same as turning except that the cutting chip is taken from the inside. The cutting edge of the boring tool resembles that of a turning tool. Boring tools may be of either the solid forged type or the inserted cutter bit type.

When the work to be bored is clamped to the top of the carriage, a boring bar is held between centers and driven by a dog. The work is fed to the tool by the automatic longitudinal feed of the carriage. Three types of boring bars are shown in figure 14–6; note the countersunk center holes at the ends to fit the lathe centers.

In figure 14–6, A illustrates a boring bar fitted with a fly cutter held by a headless setscrew. The other setscrew, bear-

ing on the end of the cutter, is for adjusting the cutter to the work.

In figure 14–6, B indicates a boring bar that is fitted with a two-edge cutter held by a taper key. This is more of a finishing or sizing cutter, as it cuts on both sides and is used for production work.

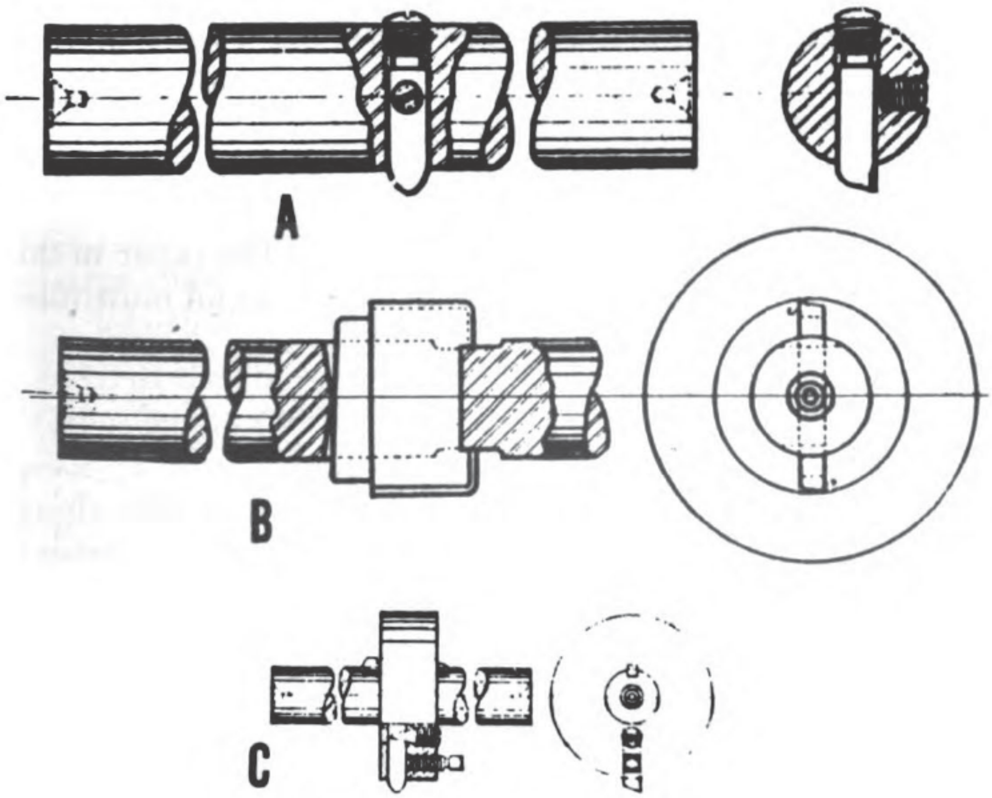


Figure 14–6.—Boring bars.

The boring bar shown in C of figure 14–6 is fitted with a cast-iron head to adapt it for boring work of large diameter. The head is fitted with a fly cutter similar to the one shown in A of figure 14–6. The setscrew with the tapered point adjusts the cutter to the work.

## TAPERS

Turning a taper is another lathe operation which you may have to perform. The term TAPER may be defined as the gradual lessening or increasing of the diameter or thickness of a piece of work toward one end. The taper of any given length of work is found by subtracting the size of the small

end from the size of the large end. Taper is usually expressed as the amount of taper per foot of length, or as an angle.

### Computing the Amount of Taper

To illustrate how the AMOUNT OF TAPER PER FOOT is computed, let us take two examples.

1. Find the taper per foot of a piece of work 2 inches long; the diameter of the small end is 1 inch, the diameter of the large end is 2 inches.

The taper per foot is found by subtracting the small diameter from the large diameter, dividing by the length of the taper, and multiplying the quotient by 12. The taper in this case is (2 inches − 1 inch) divided by 2 inches and multiplied by 12.

$$\frac{2-1}{2} \times 12, \text{ or } \tfrac{1}{2} \times 12 = 6 \text{ inches}$$

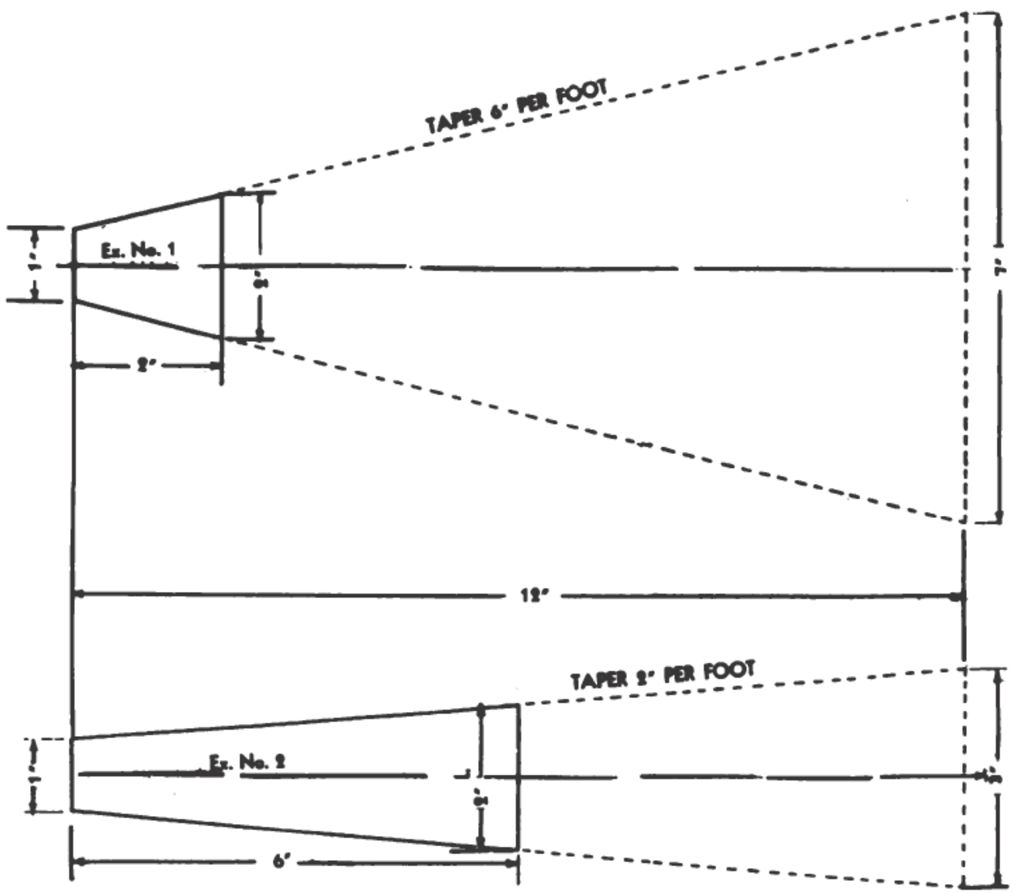



Figure 14–7.—Tapers.

Therefore the taper is 6 inches per foot. (See fig. 14–7, Ex. No. 1.)

2. Find the taper per foot of a piece 6 inches long; the diameter of the small end is 1 inch; the diameter of the large end is 2 inches.

The diameters are the same as in example 1; however, the length of this taper is 6 inches.

Hence, the taper per foot is $\frac{1}{6} \times 12$, or 2 inches. (See fig. 14–7, Ex. No. 2.)

From the foregoing, it is obvious that the length of the tapered piece is very important in computing a taper. A suggested formula for computing the length of any taper is:

$$\frac{(\text{Large diam} - \text{small diam}) \times 12}{\text{length of tapered piece}} = \text{Amount of taper per foot}$$

(All of the above measurements must be in inches.)

Now let us consider the angle of the taper. In a round piece of work, the included angle of the taper is twice the angle that the surface makes with the axis or centerline. In straight turning, it will be recalled, the diameter of a piece is reduced by twice the depth of the cut taken from its surface. In the same way, the included angle of the taper is twice the angle that the path of the cutting tool makes with the axis or centerline of the piece being turned.

## Standard Tapers

There are several well-known tapers that are recognized as standards for machines on which they are used. These standards make it possible to obtain parts to fit the machine in question without the necessity of detailed measuring and fitting. When the name and number of the standard taper being used is designated, all pertinent measurements (length, diameters, and taper per foot) are immediately obtainable by reference to appropriate tables found in machinist's handbooks.

There are tables in all machinist's handbooks that give the angles for different amounts of taper per foot. A sample of such a table follows:

| Taper per foot | Angle of the taper | | Angle of the taper surface with the centerline | | Taper per inch from centerline |
|---|---|---|---|---|---|
| | *Degrees* | *Minutes* | *Degrees* | *Minutes* | |
| 1/8 | 0 | 36 | 0 | 18 | 0.01042 |
| 3/16 | 0 | 54 | 0 | 27 | .01563 |
| 1/4 | 1 | 12 | 0 | 36 | .02083 |
| 5/16 | 1 | 30 | 0 | 45 | .02604 |
| 3/8 | 1 | 47 | 0 | 54 | .03125 |
| 7/16 | 2 | 5 | 1 | 3 | .03646 |
| 1/2 | 2 | 23 | 1 | 12 | .04167 |
| 9/16 | 2 | 41 | 1 | 21 | .04688 |
| 5/8 | 3 | 0 | 1 | 30 | .05208 |
| 11/16 | 3 | 17 | 1 | 38 | .05729 |
| 3/4 | 3 | 35 | 1 | 47 | .06250 |
| 13/16 | 3 | 53 | 1 | 56 | .06771 |
| 7/8 | 4 | 11 | 2 | 5 | .07292 |
| 15/16 | 4 | 28 | 2 | 14 | .07813 |
| 1 | 4 | 46 | 2 | 23 | .08333 |
| 2 | 9 | 32 | 4 | 46 | .16667 |

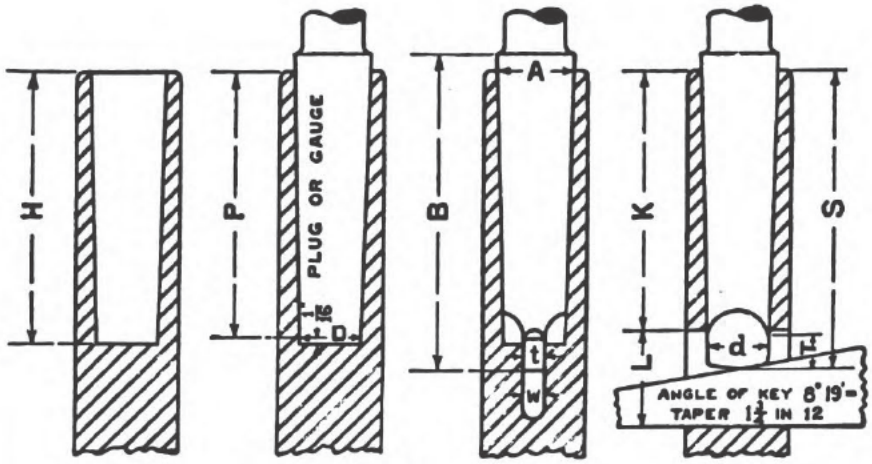
The three best known standard tapers are: (1) the MORSE TAPER (approximately 5/8 inch per foot) used for the taper holes in lathe and drill press spindles and the attachments that fit them, such as lathe centers, drill shanks, etc.; (2) the BROWN & SHARPE TAPER (1/2 inch per foot, except No. 10, which is 0.5161 inch per foot) used for milling machine spindle shanks; and (3) the JARNO TAPER (0.6 inch per foot) used by some manufacturers because of its simplicity, it being the only taper that is constant and does not require use of a table to find the various dimensions pertaining to its parts.

For example,

$$\text{diameter of large end} = \frac{\text{number of taper}}{8};$$

$$\text{diameter of small end} = \frac{\text{number of taper}}{10};$$

$$\text{length of taper} = \frac{\text{number of taper}}{2}.$$




**DETAIL DIMENSIONS**

| NUMBER OF TAPER | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| Diameter of plug at small end........D | 0.252 | 0.369 | 0.572 | 0.778 | 1.020 | 1.475 | 2.116 | 2.750 |
| Diameter at end of socket............A | .3561 | .475 | .700 | .938 | 1.231 | 1.748 | 2.494 | 3.270 |
| Shank: | | | | | | | | |
| Whole length of shank...........B | 2 11/32 | 2 9/16 | 3 1/8 | 3 7/8 | 4 7/8 | 6 1/8 | 8 9/16 | 11 5/8 |
| Shank depth.......................S | 2 7/32 | 2 7/16 | 2 15/16 | 3 11/16 | 4 5/8 | 5 7/8 | 8 1/4 | 11 1/4 |
| Depth of hole..........................H | 2 1/32 | 2 3/16 | 2 5/8 | 3 1/4 | 4 1/8 | 5 1/4 | 7 3/8 | 10 1/8 |
| Standard plug depth..................P | 2 | 2 1/8 | 2 9/16 | 3 3/16 | 4 1/16 | 5 3/16 | 7 1/4 | 10 |
| Tongue: | | | | | | | | |
| Thickness of tongue..............t | 5/32 | 13/64 | 1/4 | 5/16 | 15/32 | 5/8 | 3/4 | 1 1/8 |
| Length of tongue.................T | 1/4 | 3/8 | 7/16 | 9/16 | 5/8 | 3/4 | 1 1/8 | 1 3/8 |
| Diameter of tongue................d | .235 | .343 | 17/32 | 23/32 | 31/32 | 1 13/32 | 2 | 2 5/8 |
| Keyway: | | | | | | | | |
| Width of keyway................W | .160 | .213 | .260 | .322 | .478 | .635 | .760 | 1.135 |
| Length of keyway.................L | 9/16 | 3/4 | 7/8 | 1 3/16 | 1 1/4 | 1 1/2 | 1 3/4 | 2 5/8 |
| End of socket to keyway............K | 1 15/16 | 2 1/16 | 2 1/2 | 3 1/16 | 3 7/8 | 4 15/16 | 7 | 9 1/2 |
| Taper per foot.......................... | 625 | .600 | .602 | .602 | .623 | .630 | .626 | .625 |
| Taper per inch.......................... | .05208 | .05 | .05016 | .05016 | .05191 | .0525 | .05216 | .05208 |
| Number of key.......................... | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |

**Figure 14–8.—Morse standard tapers.**

The taper for pipe ends, ¾ inch per foot, is also considered a standard.

Since Morse tapers are used for lathe spindle holes and the attachments that fit them, a copy of a Morse taper table is shown in figure 14–8. You will no doubt have more use for this taper than for any other standard taper.

### Methods of Turning Tapers

In ordinary straight turning the cutting tool moves along a line parallel to the axis of the work, causing the finished job to be the same diameter throughout its length. If, however, the cutting tool moves at an angle to the axis of the work, the diameter of the piece being turned gradually increases or decreases from one end to the other and a taper

is produced. Therefore, to turn a taper it is necessary either to mount the work in the lathe so that the axis upon which it turns is at an angle to the axis of the lathe, or to cause the cutting tool to move at an angle to the axis of the lathe.

There are three methods in common use for turning tapers:

1. Set over the tailstock, to move the dead center away from the axis of the lathe. This causes work supported between centers to be at an angle with the axis of the lathe.

2. Use the compound rest set at an angle. This causes cause the cutting tool to move at an angle to the axis of the lathe.

3. Use the taper attachment. This also causes the cutting tool to move at an angle to the axis of the lathe.

In the first method the cutting tool is fed by the longitudinal feed parallel to the lathe axis, but a taper is produced because the work axis is at an angle. In the second and third methods the work axis coincides with the lathe axis,

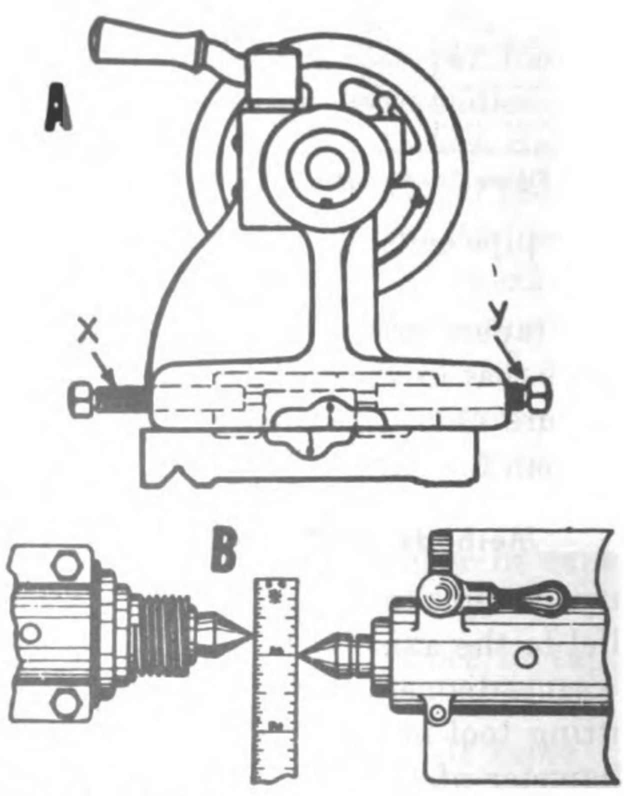



Figure 14–9.—Setting and measuring tailstock set-over for taper turning.

but a taper is produced because the cutting tool moves at an angle.

SETTING OVER THE TAILSTOCK. The tailstock may be moved laterally on its base by means of adjusting screws, indicated by X and Y in figure 14–9, A. These adjusting screws are used to align the tailstock center with the headstock center, by moving the tailstock to bring it on the centerline. For taper turning we deliberately move the tailstock off center, and the amount we move it determines the taper produced. The amount of set-over can be approximately set by means of the zero lines inscribed on the base and top of the tailstock, as shown in A of figure 14–9. Then for final adjustment, the set-over is measured with a scale between center points, as illustrated in figure 14–9, B.

In turning a taper by this method the distance between centers is of utmost importance. To illustrate the importance of considering the length of work, figure 14–10 shows how two very different tapers are produced by the same amount of set-over of the tailstock, when the length of the work between centers is greater in one case than in the other. The closer the dead center is to the live center, the steeper is the taper produced.

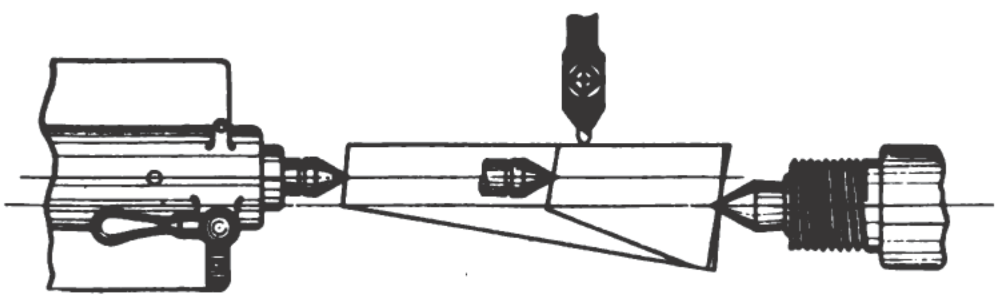


**Figure 14–10.—Significance of stock length in turning a taper by the tailstock set-over method.**

Suppose it is desired to turn a taper on the full length of a piece 12 inches long with one end having a diameter of 3 inches, and the other end a diameter of 2 inches. The small end is 1 inch smaller than the large end; so we set the tailstock over one-half this amount—½ inch in this case. Thus at one end the cutting tool will be ½ inch closer to the center

of the work than at the other end, so the diameter of the finished job will be $2 \times \frac{1}{2}$ or 1 inch less at the small end. Since the piece is 12 inches long, we have produced a taper of 1 inch per foot. Now, if we wish to produce a taper of 1 inch per foot on a piece only 6 inches long, the small end would be only ½ inch less in diameter than the large end; therefore, the tailstock would be set over ¼ inch, or one-half of the distance used for the 12-inch length.

From the foregoing it is seen that the set-over is proportional to the length between centers and may be computed by the following formula:

$$S=\frac{T}{2}\times\frac{L}{12},$$

where $S$ is the set-over in inches, $T$ is the taper per foot in inches, and $\frac{L}{12}$ is the length in feet.

Remember that $L$ is the length of the work from live center to dead center. If the work is on a mandrel, $L$ is the length of the mandrel between centers.

The tailstock set-over method is perhaps the oldest and most used method of turning tapers. However, it cannot be used for steep tapers, because the set-over necessary would be too great and the work would not be properly supported by the lathe centers. It is obvious that with set-over there is not a true bearing between the work centers and the lathe center points, and that the bearing surface becomes more and more unsatisfatory as the set-over is increased.

After turning a taper by the tailstock set-over method, don't forget to realign the centers for straight turning, to be ready for your next job.

Use of the Compound Rest. The compound rest is generally used for short, steep tapers. It is set at the angle which the taper is to make with the centerline (that is, half the included angle of the taper). The tool is then fed to the work at this angle by means of the compound rest feed screw. The length of the taper that can be machined is necessarily short because of the limited travel of the compound rest top.

Truing a lathe center is one example of the use of the compound rest for taper work (see fig. 14–1). Other examples are the refacing of a valve (illustrated in fig. 14–11), the machining of the face of a bevel gear, and similar work. Such jobs are often referred to as working to an angle rather than as taper work.

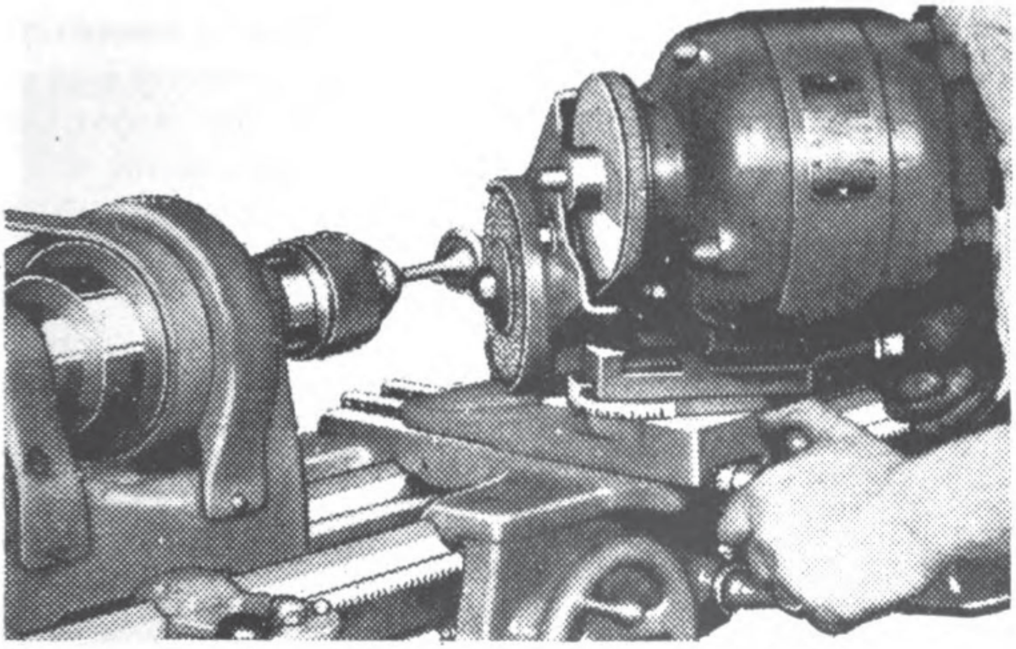


Figure 14–11.—Taper work; refacing a valve.

The graduations marked on the compound rest provide a quick means for setting it to the angle desired. When set at zero, the compound rest is perpendicular to the lathe axis. When set at 90° on either side, it is parallel to the lathe axis.

On the other hand, when the angle to be cut is measured from the centerline, the setting of the compound rest corresponds to the complement of that angle. (The complement of an angle is that angle which added to it makes a right angle; that is, angle plus complement $=90°$.) For example, to machine a 50° included angle (25° angle with centerline), the compound rest is set at $90° - 25°$, or 65°.

When a very accurate setting of the compound rest is to be made—for example, to a fraction of a degree—run the carriage up to the faceplate and set the compound rest with a bevel protractor set to the required angle. The blade of the

protractor is held on the flat surface of the faceplate and the stock is held against the finished side of the compound rest.

USE OF THE TAPER ATTACHMENT. For turning and boring long tapers with accuracy, the taper attachment (fig. 14–12) is indispensable. It is especially useful in duplicate work; identical tapers can be turned and bored with one setting of the taper guide bar.

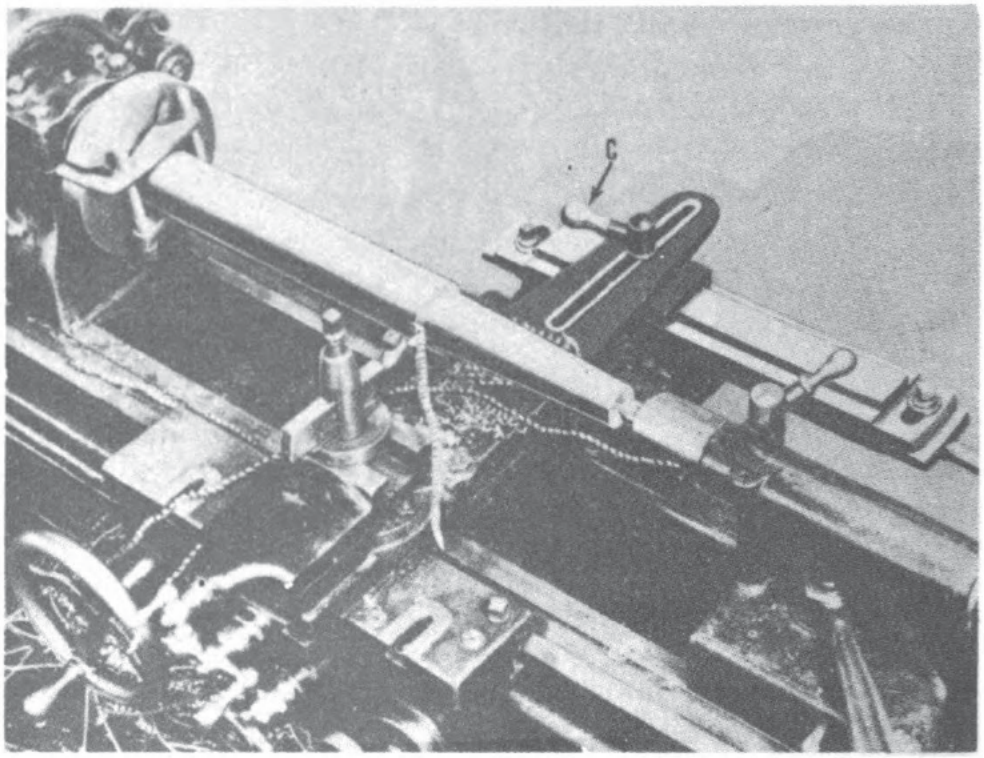



Figure 14–12.—Turning a taper with a taper attachment.

The guide bar is set at an angle to the lathe axis corresponding to the taper desired. By means of a shoe which slides on this guide bar as the carriage moves longitudinally, the tool cross slide is moved laterally. The resultant movement of the cutting tool is along a line that is parallel to the guide bar, and therefore a taper is produced whose angular measurement is the same as that set on the guide bar. To facilitate rapid setting, the guide bar is graduated in degrees at one end, and in inches per foot of taper at the other end.

When preparing to use the taper attachment, run the carriage up to the approximate position of the work to be turned.

Set the tool on line with the centers of the lathe. Then bolt or clamp the holding bracket to the ways of the bed (the attachment itself is bolted to the back of the carriage saddle). Disconnect the cross-feed nut from the cross slide of the compound rest and tighten the clamp (C in fig. 14–12). The taper guide bar now controls the lateral movement of the cross slide. Set the guide bar for the taper desired and the attachment is ready for operation. The final adjustment of the tool for size must be made by means of the compound rest feed screw, since the cross-feed screw is inoperative.

For turning tapers—or for boring them either by the use of the compound rest or the taper attachment—the cutting edge of the tool should be set exactly at the center of the work. In other words, set the point of the cutting edge even with the height of the lathe centers.

### Testing a Taper Fit

In testing the taper on a piece of work that is to fit a spindle and is nearly finished, make a chalk mark along the element or side of the taper piece. Place the work in the taper hole it is to fit and turn carefully by hand. Then remove the work, and the chalk mark will show where the taper is bearing. If the taper is a perfect fit, this will be indicated along the entire line of the chalk mark; if the fit is not perfect, the chalk mark will show where the adjustment is needed. Make the adjustment, take another light chip, and test again. Be sure the taper is correct before turning to the finished diameter.

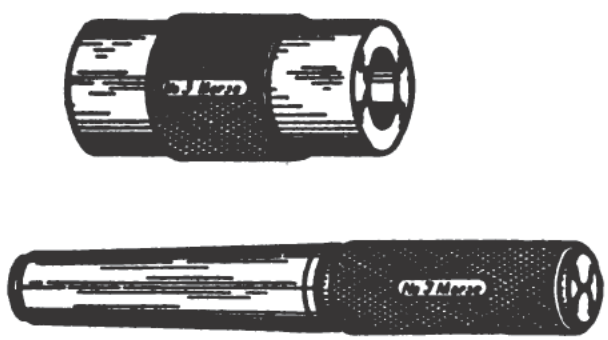


Figure 14–13.—Morse standard taper gages.

Figure 14–13 shows a Morse standard taper plug and a taper socket gage. They not only give the proper taper, but also show the proper distance that the taper should enter the spindle.

## CUTTING SCREW THREADS

The application of the screw thread is well known to all who work with machinery. The screw thread not only provides a means for fastening parts together, but is used to transmit motion and to provide leverage; and in precision instruments it is a means for measuring minute distances. The lead screw and cross-feed screw of a lathe are good examples of a screw thread used to transmit motion.

You are familiar with the various types of screw threads and you know that they differ in the form of their cross section. If you are in doubt as to applications, types, terms, and fundamentals relating to screw threads, refer to such training courses as *Use of Tools* (NavPers 10623) and *Basic Machines* (NavPers 10624), or to an engineers' handbook.

The AMERICAN NATIONAL SCREW THREAD has been established as a standard system of screw threads in the United States. This type of thread is generally used by all machine shops. However, there are applications where more strength is required than can be provided by the American National Thread. In such cases, the ACME and SQUARE THREADS are used. For example, the lead screw of a lathe has an Acme thread while a jack screw usually has a square thread.

Since the American National Thread is the most commonly used, tables for both the Coarse thread series (NC) and the Fine thread series (NF) are given in the table on page 451.

Cutting screw threads in the lathe is accomplished by connecting the headstock spindle of the lathe with the lead screw by a series of gears in such a way that a positive carriage feed is obtained and the lead screw is driven at the required speed with relation to the headstock spindle. The gearing between the headstock spindle and lead screw may be arranged so that any desired pitch of the thread may be cut. For ex-

### Tables of American National Standard Screw Thread Pitches and Recommended Tap Drill Sizes

**Coarse Thread Series, Standard Thread (NC) (Formerly U. S. Standard)**

| No. or diameter | Threads per inch | Outside diameter of screw | Tap drill sizes | Decimal equivalent of drill |
|---|---|---|---|---|
| 1 | 64 | 0.073 | 53 | 0.0595 |
| 2 | 56 | .086 | 50 | .0700 |
| 3 | 48 | .099 | 47 | .0785 |
| 4 | 40 | .112 | 43 | .0890 |
| 5 | 40 | .125 | 38 | .1015 |
| 6 | 32 | .138 | 36 | .1065 |
| 8 | 32 | .164 | 29 | .1360 |
| 10 | 24 | .190 | 25 | .1495 |
| 12 | 24 | .216 | 16 | .1770 |
| 1/4 | 20 | .250 | 7 | .2010 |
| 5/16 | 18 | .3125 | F | .2570 |
| 3/8 | 16 | .375 | 5/16 | .3125 |
| 7/16 | 14 | .4375 | U | .3680 |
| 1/2 | 13 | .500 | 27/64 | .4219 |
| 9/16 | 12 | .5625 | 31/64 | .4843 |
| 5/8 | 11 | .625 | 17/32 | .5312 |
| 3/4 | 10 | .750 | 21/32 | .6562 |
| 7/8 | 9 | .875 | 49/64 | .7656 |
| 1 | 8 | 1.000 | 7/8 | .875 |
| 1 1/8 | 7 | 1.125 | 63/64 | .9843 |
| 1 1/4 | 7 | 1.250 | 1 7/64 | 1.1093 |

**Fine Thread Series, Standard Thread (NF) (Formerly S. A. E.)**

| No. or diameter | Threads per inch | Outside diameter of screw | Tap drill sizes | Decimal equivalent of drill |
|---|---|---|---|---|
| 0 | 80 | 0.060 | 3/64 | 0.0469 |
| 1 | 72 | .073 | 53 | .0595 |
| 2 | 64 | .086 | 50 | .0700 |
| 3 | 56 | .099 | 45 | .0820 |
| 4 | 48 | .112 | 42 | .0935 |
| 5 | 44 | .125 | 37 | .1040 |
| 6 | 40 | .138 | 33 | .1130 |
| 8 | 36 | .164 | 29 | .1360 |
| 10 | 32 | .190 | 21 | .1590 |
| 12 | 28 | .216 | 14 | .1820 |
| 1/4 | 28 | .250 | 3 | .2130 |
| 5/16 | 24 | .3125 | I | .2730 |
| 3/8 | 24 | .375 | Q | .3320 |
| 7/16 | 20 | .4375 | 25/64 | .3906 |
| 1/2 | 20 | .500 | 29/64 | .4531 |
| 9/16 | 18 | .5625 | .5062 | .5062 |
| 5/8 | 18 | .625 | .5687 | .5687 |
| 3/4 | 16 | .750 | 1 1/16 | .6875 |
| 7/8 | 14 | .875 | .8020 | .8020 |
| 1 | 14 | 1.000 | .9274 | .9274 |
| 1 1/8 | 12 | 1.125 | 1 3/64 | 1.0468 |
| 1 1/4 | 12 | 1.250 | 1 11/64 | 1.1718 |

ample, if the lead screw has 8 threads per inch and the gears are arranged so that the headstock spindle makes four complete revolutions while the lead screw is making only one revolution, the thread cut will be four times as fine as the thread on the lead screw, or 32 threads per inch. With a quick-change gear box, the proper gearing arrangement for the thread desired can be made quickly and easily by placing the levers as indicated on the index plate.

When the lathe is set up to control the movement of the carriage for cutting the pitch of the thread desired, the next consideration is the shaping of the thread. The cutting tool is ground to the shape required for the form of the thread to be cut: V, Acme, square, etc. The depth of the thread is obtained by adjusting the cross slide.

### Mounting the Work in the Lathe

When mounting work between the lathe centers for cutting screw threads, make sure that the lathe dog is securely attached before starting to cut the thread. If the dog should slip, the thread will be ruined. Never remove the LATHE DOG from the work until the thread has been completed, and if it is necessary to remove the work from the lathe before the thread is finished, make sure that the lathe dog is replaced in the same slot of the driving plate.

When threading work in the lathe chuck, make sure that the chuck jaws are tight and that the work is well supported. The chuck must be tight enough on the spindle to prevent unscrewing when the lathe is reversed. Never remove the WORK from the chuck until the thread is finished.

When threading long slender shafts, use a follower rest. The center rest may be used for supporting one end of long work that is to be threaded on the inside.

### Tools for Cutting American National Threads

The point of the tool must be ground to an angle of 60°, as shown in figure 14–14. A center gage or a thread-tool gage is used for grinding the tool to the exact angle required. The top of the tool is usually ground flat, with no side rake

or back rake. However, for cutting threads in steel, side rake is sometimes used.

A formed threading tool is generally used if considerable threading is to be done. Formed threading tools require grinding on the top edge only to sharpen and therefore always remain true to form and correct angle.

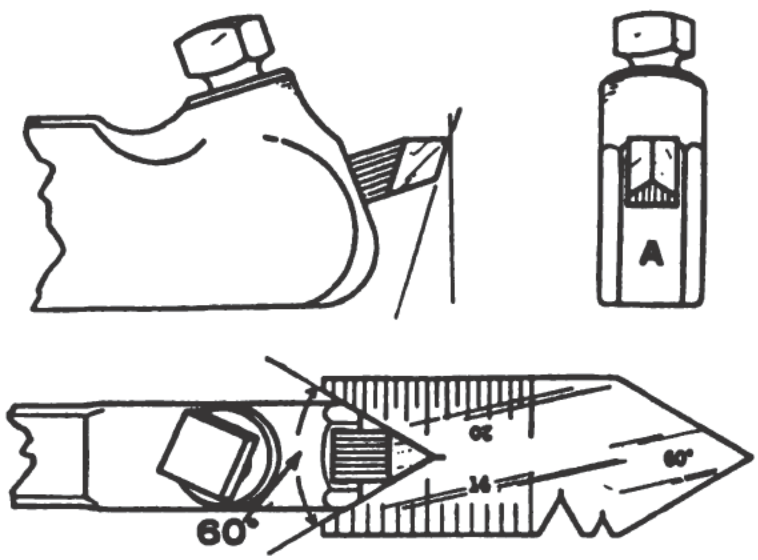
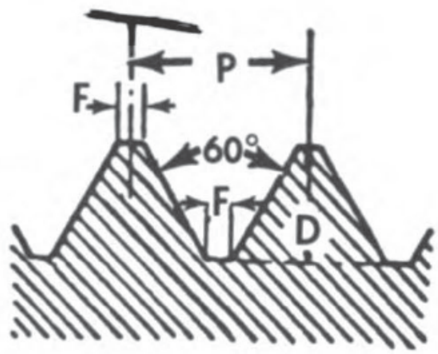


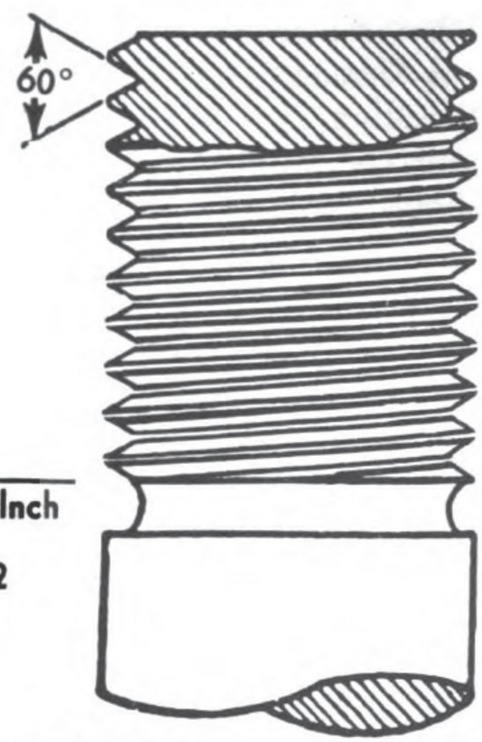

Figure 14–14.—Threading tool for American National Standard screw threads.

For cutting American National Standard screw threads finer than 10 per inch, the point of the tool is usually left sharp or with a very small flat TO PROVIDE CLEARANCE at the bottom of the thread. However, for cutting coarse pitches of thread, and when maximum strength is desired, the point of the tool may be ground flat to conform to the exact shape of the thread. The flat on the point of the tool should be one-eighth of the pitch. (See fig. 14–15.)

For EXTERNAL THREAD CUTTING, the top of the threading tool should be placed exactly on center as shown in A of figure 14–16. Note that the top of the tool is ground flat and is in exact alignment with the lathe center. This is necessary to obtain the correct angle of the thread.

The threading tool must be set square with the work, as shown in B of figure 14–16. The center gage is used to adjust the point of the threading tool and if the tool is carefully set, a perfect thread will result. Of course, if the




FORMULA

$$P = \text{PITCH} = \frac{1}{\text{No. Threads per Inch}}$$

$$D = \text{DEPTH} = P. \times .64952$$

$$F = \text{FLAT} = \frac{P}{8}$$

Figure 14–15.—American National Standard screw thread.

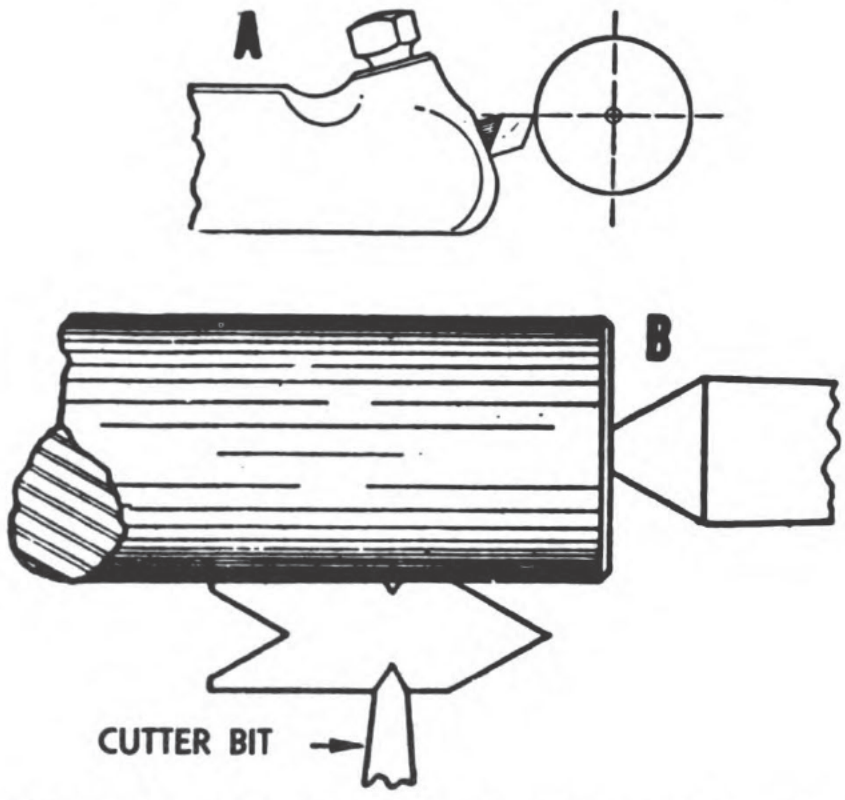



Figure 14–16.—Setting the threading tool for cutting external screw threads.

threading tool is not set perfectly square with the work, the angle of the thread will be incorrect.

For INTERNAL THREAD CUTTING, the point of the threading tool is also placed exactly on center (fig. 14–17, A). The point of the tool must be set perfectly square with the work. This may be accomplished by fitting the point of the tool into the center gage which is set square with the work as shown in B of figure 14–17.

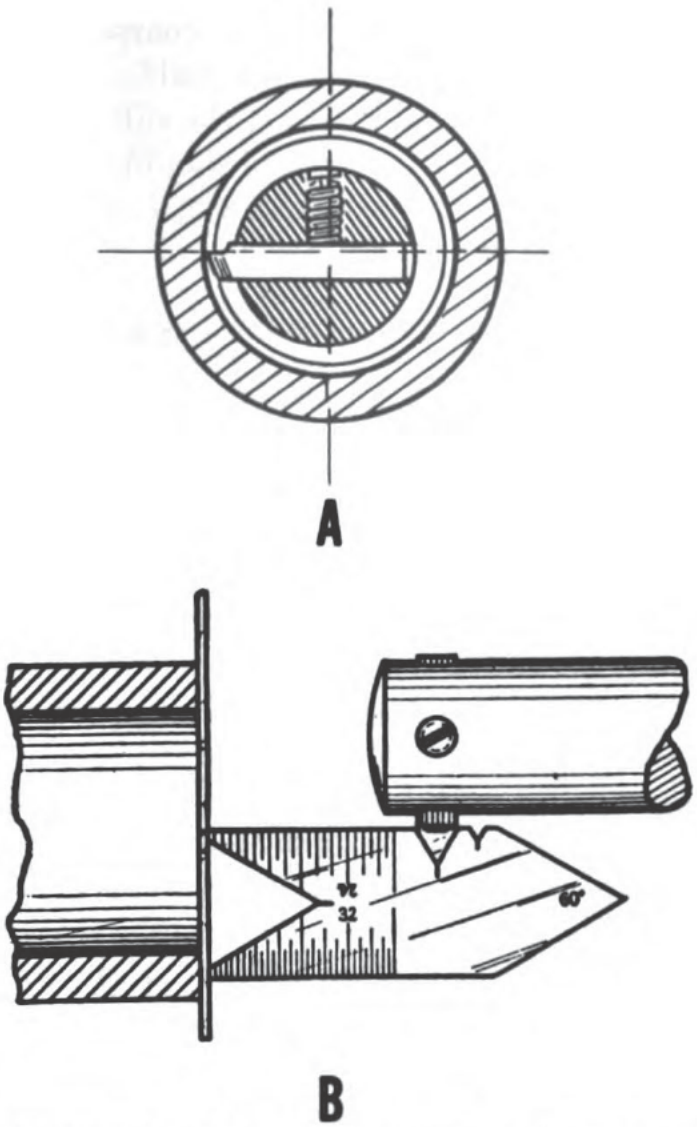



**Figure 14–17.—Setting the threading tool for cutting internal threads.**

The size of the threading tool for cutting an internal thread is important, because the tool head must be small enough so that it can be backed out of the thread and still

leave enough clearance so that it can be drawn from the threaded hole without injuring the thread. However, the boring bar which holds the threading tool for internal threading should be as large in diameter and as short in length as possible, to prevent springing.

### Position of Compound Rest for Cutting Screw Threads

Ordinarily on threads of fine lead, the tool is fed straight into the work in successive cuts. For coarse threads it is better to set the compound rest at one-half of the included angle of the thread, and feed in along the side of the thread. For the last few finishing cuts the tool should be fed straight in with the cross-feed of the lathe to make a smooth finish on both sides of the thread.

### Use of the Thread-Cutting Stop

On account of the lost motion caused by the play necessary for smooth operation of the change gears, lead screws, half-nuts, etc., the thread-cutting tool must be withdrawn quickly at the end of each cut, before the lathe spindle is reversed to return the tool to the starting point. If this is not done, the point of the tool will dig into the thread and may be broken off.

To reset the tool accurately for each successive cut and to regulate the depth of the chip, the adjustable thread-cutting stop (fig. 14–18) is useful.

First set the point of the tool so that it just touches the work, then lock the thread-cutting stop and turn the thread-cutting stop adjusting screw until the shoulder is tight against the thread-cutting stop. When ready to take the first chip, run the tool rest back by turning the cross-feed screw to the left several times, and move the tool to the point where the thread is to start. Then turn the cross-feed screw to the right until the thread-cutting stop screw strikes the thread-cutting stop. The tool rest is now in the original position, and turning the compound rest feed screw in will place the tool in a position to take the first cut.

For each successive cut after the carriage is returned to its starting point, the tool can be reset accurately to its previous position by turning the cross-feed screw to the right until the shoulder of the adjusting screw strikes the thread-cutting stop. Then the depth of the next cut can be regulated by adjustment of the compound rest feed screw as for the first chip.

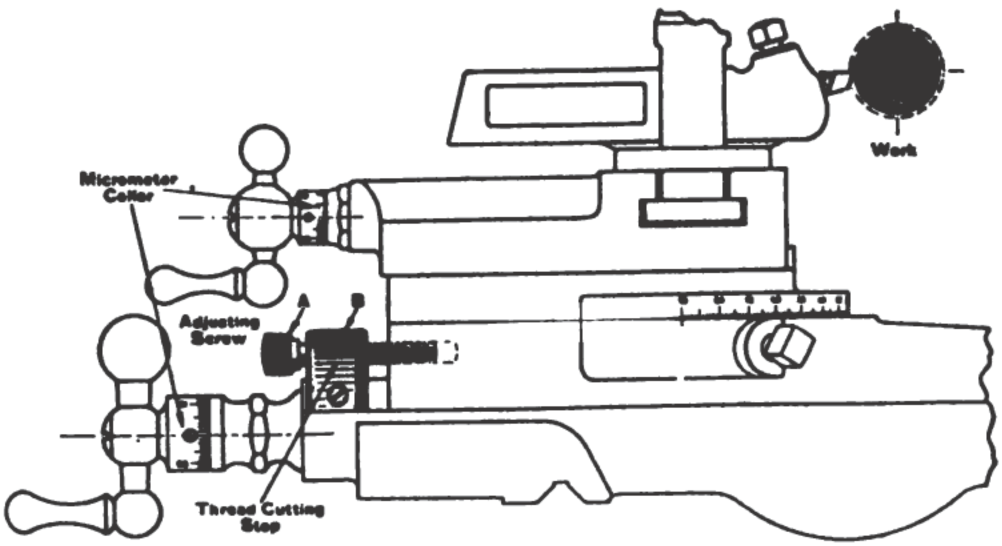



Figure 14–18.—The thread-cutting stop attached to the dovetail of the carriage saddle.

For cutting an internal thread, the adjustable thread-cutting stop should be set with the head of the adjusting screw on the inside of the stop, because in this case the tool is withdrawn by moving it toward the center or axis of the lathe.

The micrometer collar on the cross-feed screw may be used in place of the thread-cutting stop, if desired. To do this, first bring the point of the threading tool up so that it just touches the work; then adjust the micrometer collar on the cross-feed screw to zero. All adjusting for obtaining the desired depth of cut should be done with the compound rest screw. Withdraw the tool at the end of each cut by turning the cross-feed screw to the left one complete turn, return the tool to the starting point, and turn the cross-feed screw to the right one turn, stopping at zero. The compound rest feed screw may then be adjusted for any desired depth of chip.



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## Returning the Carriage to the Starting Point

The two practical methods of returning the carriage to the starting point after taking a threading cut are:

1. By reversing the direction of spindle rotation, causing the carriage to run back automatically.

2. By opening the split nut and running the carriage back by hand, using the thread dial to engage the split nut.

When cutting short threads, it is better to leave the half-nuts engaged with the lead screw; when the end of the cut is reached, withdraw the tool and reverse the lathe spindle to return the tool to the starting point.

A thread dial indicator or threading clock is generally used for cutting long screw threads. This device permits disengaging the half-nuts at the end of the cut, returning the carriage to the starting point by hand, and then engaging the half-nuts at the correct time so that the tool will follow in the groove of the original cut. This procedure saves time and also eliminates the necessity of reversing the lathe spindle.

## Cutting the Thread

After setting up the lathe, as explained previously, take a very light trial cut just deep enough to scribe a line on the surface of the work. The purpose of this trial cut is to make sure that the lathe is arranged for cutting the desired pitch of thread.

To check the number of threads per inch, place a scale against the work (see A of fig. 14–19), so that the end of the scale rests on the point of the thread or on one of the

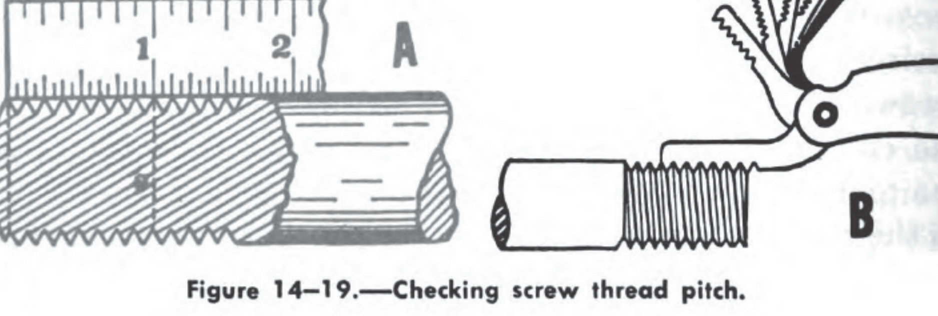



Figure 14–19.—Checking screw thread pitch.

scribed lines. Determine the number of spaces between crests on that part of the threaded piece lying between the end of the scale and the first inch mark; this will be the number of threads per inch.

It is quite difficult to accurately count fine pitches of screw threads, as described above. A screw-thread gage, used as indicated in B of figure 14–19, is very convenient for checking the finer screw threads. This gage consists of a number of sheet-metal plates in which are cut the exact form of threads of the various pitches, and each plate is stamped with a number indicating the number of threads per inch for which it is to be used.

The final check for both the diameter and pitch of the thread may be made with the nut that is to be used or with a ring thread gage, if one is available. The nut should fit snugly without play or shake but should not bind on the thread at any point.

### Use of a Lubricant for Cutting Threads

In order to produce a smooth thread when cutting screw threads in steel, lard oil should be used. If the oil is not used, the cutting tool will tear the steel and the finish will be very rough.

If lard oil is not available, any good cutting oil or machine oil may be used. If trouble is experienced in producing a smooth thread, a little powdered sulfur may be added to the oil. Before a cut is made, oil should be applied generously. A small paint brush is ideal for applying the oil when cutting external screw threads. Since lard oil is quite expensive, many mechanics place a small tray or cup just below the cutting tool on the cross slide of the lathe, to catch the surplus oil which drips off the work.

### Resetting the Tool After the Thread Has Been Started

If the thread-cutting tool should need resharpening, or if for any other reason it is necessary to remove the thread-cutting tool before the thread has been completed, the tool must be carefully readjusted so that it will follow the original

groove when it is replaced in the lathe. There are several methods by which this can be accomplished.

Before adjusting the tool, set the point of the tool square with the work, and take up all the lost motion in the change gears, half-nuts, etc., by turning the spindle forward by hand. In rotating the spindle to reset the thread tool, always turn it forward. If you turn it backward, there will be a backlash and the setting will not show the true position of the tool.

One method of resetting the tool in the thread groove is to set the compound rest at an angle, and adjust the cross-feed screw and compound rest feed screw simultaneously so that the point of the tool can be made to enter exactly into the original groove.

If it is not convenient to use the compound rest for readjusting the threading tool, the lathe dog may be loosened, the work turned so that the threading tool will match the groove, and the lathe dog then tightened. If possible, however, avoid the necessity of doing this.

Another method that is sometimes used is to disconnect the reverse gears or the change gears, turn the headstock spindle until the point of the threading tool enters the groove in the work, and then reconnect the gears.

### Finishing the End of a Threaded Piece

The end of the thread may be finished by any one of several methods. The 45° chamfer on the end of the thread, as shown in A of figure 14–20, is commonly used for bolts, cap screws, etc. For machined parts and special screws the end is often finished by rounding with a forming tool. (See fig. 14–20, B.)

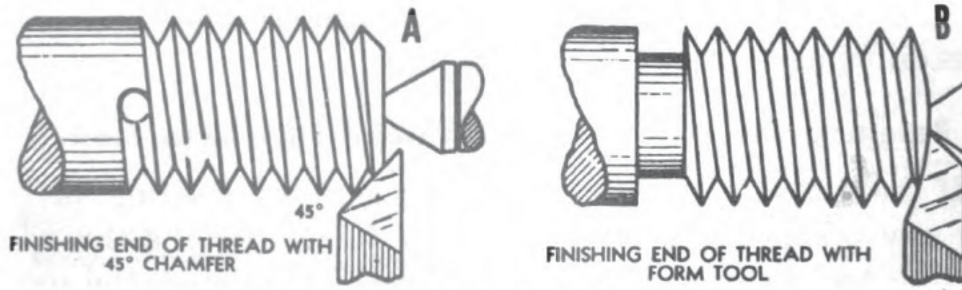



Figure 14–20.—Finishing the end of a threaded piece.

It is difficult to stop the threading tool abruptly, so some provision is usually made for clearance at the end of the cut. In figure 14–20, A indicates that a shallow hole has been drilled at the end of the thread, and B shows that a neck or groove has been cut around the shaft. The groove is preferable, as the lathe must be run very slowly in order to obtain satisfactory results with the drilled hole.

## SUMMARY

This chapter covers all that the MM1 or C is required to know about lathe machining operations.

The section on turning describes the surface machining of a piece of stock.

The section on boring describes the process of machining an interior cylindrical or a drilled surface.

The section on tapers provides formulas for computing the amount of taper and the angle of taper, and describes commonly used methods of turning tapers.

The section on screw threads gives detailed instructions on how to cut fine and coarse threads, and how to set the tool for internal and external thread cutting.

## QUIZ

1. When a grinding attachment is used to true a lathe center, the compound rest must be seated at an angle of how many degrees?
2. How is the alignment of centers checked when the work to be machined is long and accuracy is required?
3. After centers have been aligned and work mounted, what is the first machining operation if the work is to be accurate?
4. In machining on centers, carriage travel should be, if possible, in what direction?
5. What is the advantage of machining rough cuts to a shoulder which has been located with a cut-off tool?
6. When taking a roughing cut on steel, if you desire to reduce the diameter of a piece by ⅛ of an inch, what fraction of the metal must be removed from the surface?
7. When should a finishing cut be taken?
8. What is regarded as the most difficult operation in machine work?
9. How is machining to a shoulder generally performed?
10. When machining a hole by the boring process, what must be done to the work before the boring tool is used?

11. In single point boring, is the boring tool fed to the work, or is the work fed to the tool?
12. What term is used to define the gradual lessening or increasing of the diameter or thickness of a piece of work toward one end?
13. What is the taper per foot of a piece of work two feet long, if the diameter of the small end is 2 inches and the diameter of the large end is 3 inches?
14. In a round piece of work, what is the relationship between the included angle of the taper and the angle that the surface makes with the axis or centerline?
15. What standard taper is used for the spindle holes of a lathe?
16. Of the three common methods used for turning tapers, in which does the cutting tool move parallel to the axis of the lathe?
17. If a shaft 12 inches long is to be turned with a 2-inch diameter at the large end and a full length taper of 1 inch per foot, how much should the tailstock be set over?
18. When the taper attachment is being used, does the cutting tool move along a line parallel to or at an angle to the axis of the lathe?
19. When the taper attachment is used, is the final adjustment of the cutting tool made with the compound rest feed screw or with the cross-feed screw?
20. What type of thread is generally used by all machine shops?
21. When cutting threads on work mounted between centers, what two precautions must be taken if the work is removed from the lathe before the thread is finished?
22. What precautions should be taken when threading work in the lathe chuck?
23. For cutting American National screw threads, to what number of degrees must the included angle of the cutting tool be ground?
24. In cutting an external screw thread, how is the depth of each successive cut regulated?
25. When an internal thread is to be cut, why is the adjustable thread-cutting stop set with the head of the adjusting screw on the inside of the stop?
26. Why should the first cut of a screw thread be light enough to only scribe a line?
27. If a gage is not available, what may be used to make the final check for both the diameter and pitch of a screw thread?
28. In order to produce a smooth thread, what lubricant should be used when cutting screw threads in steel?
29. What is sometimes added to a cutting tool for the purpose of improving the finish of the screw thread?
30. What may be done to provide clearance for the cutting tool at the end of a screw thread?

# CHAPTER 15

# INSPECTION, MAINTENANCE, AND REPAIR OF AUXILIARY EQUIPMENT

Aboard ship there are a number of auxiliary machinery units (some of them located outside the engineering spaces) with which the Machinist's Mate must be familiar. This chapter provides general information on the care and maintenance of steering and hoisting mechanisms, hydraulic systems, compressed air systems, and auxiliary boilers.

## STEERING GEAR

Aboard modern naval vessels, practically all steering mechanisms are hydraulically driven. Since you may be responsible for maintenance or repairs on steering gears, particularly on variable-stroke hydraulic rotary pumps and other component parts of the hydraulic system, you should familiarize yourself with this type of equipment. Your best source of information will be the manufacturers' instruction books.

### Remote Control

The remote control of steering gears on most modern ships is accomplished electrically, by means of alternating-current synchronous transmission. However, you may encounter some systems in which remote control is accomplished hydraulically by means of a telemotor system, or mechanically by means of shafting or wire rope from the steering station.

THE HYDRAULIC TELEMOTOR type of remote control is installed aboard many auxiliary ships of the Navy. On this type of control, maintenance usually consists of nothing more than the prevention of leaks in the hydraulic system and the proper care of the fluid.

Frequent inspections of the valves and joints will greatly help in eliminating and preventing leaks in the system. If the piston of an internally packed telemotor is leaking, check the condition of the leathers and make certain the springs, if installed, keep the leather in contact with the inside wall of the telemotor cylinders. Leaks in an externally packed telemotor can usually be stopped by tightening the glands just enough to cause the packing to be compressed about the rams.

Hydraulic fluid characteristics are very important if the telemotor system is exposed to low temperatures. When such conditions exist, the system should be filled with a high grade mineral oil having a cold pour of $-24°$ to $-40°$ F. When low temperatures are not involved, or if special oil with the designated cold pour cannot be obtained readily, the Navy Symbol 2075H oil can be used satisfactorily. A good hydraulic fluid must have a low rate of expansion and be adequately viscous at 150° F.

Every possible precaution should be taken to prevent contamination of the oil by condensate or other water. When the system is being filled with hydraulic fluid, the oil should be strained into the charging tank through four to six layers of cheesecloth. In this way, small amounts of water and other foreign matter are prevented from entering the system. Such precautionary measures will aid in keeping a hydraulic telemotor type of remote control in satisfactory operating condition.

THE WIRE-ROPE type of remote control is installed on some older destroyers and on some recently built small ships. The wire ropes of this control, connecting the steering engine control mechanism to the steering wheel, are the principal parts which require maintenance.

Wire ropes should be removed and carefully inspected at least every six months. If the ropes are in satisfactory con-

dition, they should be thoroughly covered with Albany grease and graphite before being replaced. If there is any indication of stranding, the affected part must be repaired or a new rope reeved. If a new rope is to be reeved, care must be taken that the stretch is taken up, otherwise the rope may foul or leave the drums and sheaves. When the ropes are inspected, all keys in the transmission shafting must be carefully examined to see that they are tight and properly seated.

Chains or Rods. Rudder movement on some auxiliary ships is accomplished by steering chains or rods, with spring buffers usually provided to absorb shock. The buffer springs, chains, and rods should be inspected at least every six months, and must be kept well lubricated at all times.

### Hydraulic Rams

Since portions of the rams in an electrohydraulic steering gear are exposed where they fit into the cylinders, it is necessary to take precautions against possible damage to such surfaces. The exposed surfaces of rams should not be used as walkways. In addition, they should be protected from water and from rolling or falling objects, and should be kept covered with a coat of prescribed rust-preventive compound or with the appropriate Navy Symbol oil. Frequent inspections should be made during operation, in order to detect any evidence of damage. A guard placed over the exposed parts will offer protection against rolling objects, and the compartment should be kept free of loose gear that might slide into the rams.

Regardless of the precautions taken, rust may accumulate on hydraulic rams. Such accumulations should be removed from the rams with a wire brush. However, during the cleaning process, clean cloths must be used to cover any exposed surface of the part which slides in and out of the cylinder. Otherwise, pieces of wire and dirt may stick to the rams and be drawn into the cylinders.

Packing followers should be kept only tight enough to maintain sufficient pressure on the rings to prevent leakage.

Overtightening should be avoided, since excessive pressure usually results in rapid wear and improper functioning of the packing.

The oil in the high-pressure hydraulic system of a steering gear should be filtered about every six months. Poor filtering results in the accumulation of foreign matter injurious to the rams and to the variable stroke pumps. Makeup oil should be filtered before it is added to the system. When the system is drained into the base tank, accumulated foreign matter can be filtered out by pumping the oil through the filters to the expansion tanks. The oil is then drained back into the storage tanks and the system refilled with the filtered oil.

## ANCHOR WINDLASSES

The types of windlasses which a Machinist's Mate will probably have to maintain are the electrohydraulic and the hand-driven. In maintaining a hand windlass, the major factor is to keep the linkage, friction shoes, locking head, and brake in proper adjustment and in satisfactory operating condition at all times. In maintaining an electrohydraulic windlass, your principal concern will be the hydraulic system. Since hydraulic systems are basically the same, the information given under "Hydraulic Systems," later in this chapter, is applicable to steering gear, windlass, winch, crane, and elevator.

Even though used intermittently and only for relatively short periods of time, a windlass must be capable of handling the required load under extremely severe conditions. To prevent deterioration and to provide dependable operation whenever required, maintainenance and adjustment must be continued during the periods when the machinery is not in use.

Windlass brakes must be maintained in satisfactory condition if they are to perform their function properly. Because of wear and compression of brake linings, the clearance between the brake drum and band will increase after a windlass has been in operation. Means of adjustment are pro-

vided on all windlass brakes. Since maladjustment of a windlass brake could result in the loss of the anchor and chain, it is advisable that you become familiar with maintenance procedures as recommended by the manufacturer.

Lubrication instructions furnished by the manufacturer should be carefully followed. If a windlass has been idle for some time, lubrication of the equipment should be accomplished before operation is attempted. After a windlass has been used, the equipment should be lubricated to protect finished surfaces from corrosion.

The hydraulic transmissions of electrohydraulic windlasses and other auxiliaries are manufactured with close tolerances between moving and stationary parts. If these tolerances are to be maintained and unnecessary wear prevented, every precaution possible must be taken to prevent the entry of dirt and other abrasive material. When the system is replenished or refilled, only clean oil should be used and the oil should be strained as it is poured into the tank. If a hydraulic transmission has been disassembled, all parts should be thoroughly cleaned before reassembly. Before piping or valves are installed, their interiors should be cleaned to remove any scale, sand, or other foreign matter.

## WINCHES AND CRANES

In several respects, the maintenance of a winch is similar to that of a windlass. Where band brakes are used on the drums, the friction linings should be inspected regularly and replaced when necessary. Steps should be taken to prevent oil or grease from accumulating on the brake drums. The operation of brake-actuating mechanisms, latches, and pawls should be checked periodically.

Winch drums driven by friction clutches should be inspected frequently to determine if deterioration has occurred in the friction material, or if oil and grease are preventing proper operation. The sliding parts of positive clutches must be properly lubricated, and the locking device on the shifting gear should be checked to determine if it will hold

under load. The oil of gear reduction units should be checked for proper amount, temperature, and purity. Periodic inspections should be made of the pressure lubrication fittings normally installed on slow-moving parts. On installations which use hydraulic transmission, the pumps and lines are maintained in the same way as those of any other hydraulic system.

As with many other auxiliary units, the cranes you maintain may be driven by hydraulic transmissions, by electric motors, by Diesel engines, or by hand. Maintenance should be accomplished in accordance with manufacturers' instructions. In general, the maintenance of electrohydraulic cranes requires that the oil in the replenishing tanks be kept at the prescribed levels, and that the system be kept clean and free of air. The limit stop and other mechanical safety devices must be checked regularly for proper operation. When cranes are not in use, they should be secured in their stowed positions and all electric power to the crane controllers disconnected at the power distribution panel.

## ELEVATORS

Carriers are provided with two or more electrohydraulic elevators, capable of handling airplanes between the flight and hangar decks at relatively high speed. As an MM1 or C, you may not be called upon too frequently to maintain this type of machinery. However, if you are required to maintain electrohydraulic elevators, you will find maintenance procedures relatively the same as for other auxiliaries which use fluid to transmit power.

Elevator cables and fittings should be inspected frequently, and the tension of the cables in each group kept equal. Frequent inspections must be made to ensure that (1) there is proper oil level in the pressure and exhaust tanks, (2) there is no excessive leakage in the sump leak-off connections, (3) the pistons seal properly in the hydraulic cylinders, and (4) the entire system is clean. If an elevator is not to be used immediately, it should be locked in its normal position at the flight deck.

The over-all efficiency of hydraulic installations used to control or drive auxiliary machinery is basically dependent upon size of installation, oil pressure speed, and stroke. However, the care given the hydraulic speed gears and the components of the system is also an important factor. Major repair of hydraulic gear, except for piping and fittings, is generally performed at a naval shipyard or by the manufacturer.

Hydraulic transmissions are sturdy, proven machines, inspected and tested with such care that casualties seldom occur except as a result of faulty assembly, installation, or maintenance. If a properly installed hydraulic system is operated regularly and maintained with proper care, it will retain its design characteristics of power, speed, and control, and the need for costly repair and replacement will seldom occur.

## Maintenance

Regular operation, proper lubrication, proper maintenace of all the units, and cleanliness of the fluid are principal requirements for keeping a hydraulic transmission in satisfactory operating condition. Regular operation of hydraulic equipment prevents corrosion, sludge accumulation, and freezing of adjacent parts. The need for proper lubrication and cleanliness cannot be too strongly emphasized.

Detailed instructions concerning the maintenance of a specific unit may be obtained from the appropriate instruction book; however, the general information which follows will also be helpful.

PIPING AND FITTINGS. If properly installed, hydraulic piping and valves are seldom a source of trouble, except for leakage. Some leaks may become serious enough to cause a reduction in the efficiency of the unit(s). Therefore, frequent inspections for leakage should be made and necessary steps taken to eliminate it.

If leaks occur at a flanged joint in the line of a hydraulic

system, tighten the flange bolts evenly, but not excessively. If the leaks persist, use the auxiliary gear while the gasket of the leaking flange is being replaced. Make certain that the flange surfaces are cleaned carefully before the gasket is applied.

If certain measures are taken, operation of hydraulic equipment may be continued while leakage repairs are being made in some parts of the system. When lines in an auxiliary system leak, they should be valved off from the main line connection to prevent leakage between the two systems. If leaks occur in the pumping connections to the 3-way valves of a steering gear installation, the pump can be cut out with the valve, and another pump cut in. If the 3-way valves fail to cut out the leaking unit, and it becomes necessary to cut out both pumps of a steering gear installation, the valves may be closed at the ram cylinder. Since hydraulic systems will work without pressure control, leaking pipes or cylinders of the pressure control can be cut out of the system for repairs, by closing the valves in the lines where they join the main piping. Expansion and replenishing lines in hydraulic systems of older ships are not under appreciable pressure, and therefore are seldom a source of leakage or breakage; however, all connections must be maintained intact. In the case of recent installations, replenishing lines are under pressure of as much as 300 psi, and the hydraulic system should not be operated during repair of these lines.

Relief valves or shuttle valves of a hydraulic system may be sources of trouble. The seats of leaking relief valves should be reground. Loss of power indicates a leaking relief valve. Shuttle valves may stick and fail to cut off. Existence of this condition is indicated when oil escapes from the high-pressure side of the line into the expansion tank, or when the pressure control fails. When a shuttle valve fails to operate, the stop valves should be closed and the defective valve removed for repairs.

Fluid System. When inspection of an oil sample drawn from a hydraulic system reveals the presence of water, sludge, or acidity, the system must be drained, cleaned with the pre-

scribed flushing oil, and filled with clean oil. The system may be drained and cleaned as follows:

1. Remove the filters and wash them in the flushing oil. Then use low-pressure air for drying purposes.

2. Drain the system, as completely as possible, of old oil.

3. Close all connections and fill the system with flushing oil.

4. Start and operate the unit under idling condition, in order to fill the system thoroughly with the flushing oil.

5. Secure the unit and allow it to stand idle for approximately one hour. This idle period permits the flushing oil to dissolve any sludge.

6. Start and operate the unit under light load for 3 to 5 minutes, unless otherwise specified. Then allow the equipment to remain idle for about 15 minutes, and repeat the entire process. Do this two or three times.

Never operate a hydraulic unit under full load when it is filled with flushing oil, and keep the operating pressure as low as possible.

After each short operating period, turn the cleaning handles of edge type filters (if installed) and drain from the filter an amount of oil equal to its volume.

7. If time permits, allow the system to stand idle for an additional hour following the series of short operating periods.

8. Drain the system of flushing oil, close the system, and fill it with the proper hydraulic oil.

As the system is being filled, the oil should be strained through a fine wire screen of 200 mesh. If the oil is not clean, it should be run through a centrifuge. Adequate protection should be provided against dust and moisture. Moisture should be expelled from oil before it is poured into a system; this can be done by heating the oil to 250° F.

When a hydraulic system is being filled, sufficient fluid should be used to completely fill the active parts of the mechanism, leaving no air pockets. During the filling procedure, air valves should be opened so that air can escape to the oil

expansion box. After the system has been filled, the valves should be closed tight.

PUMPS AND MOTORS. An electric motor is provided to rotate the hydraulic A or pump-end variable speed gear (rotary, positive displacement, variable stroke pump). Oil under pressure is delivered from the A end to the hydraulic motor or B end variable speed gear through piping. The B end rotates the individual unit or equipment through suitable reduction gearing. Whether the A-ends and B-ends of hydraulic transmissions are of the axial- or radial-piston type, maintenance procedures and operating principles are relatively the same. In general, maintenance information on other type pumps also applies to hydraulic pumps and motors.

On some modern hydraulic speed gears, the SHAFT STUFFING BOX PACKING is of the square-braided pure asbestos type. This type packing is easily removed. Care must be taken to ensure that it is not replaced too tightly; if properly installed, this packing makes a tight joint with light pressure. If packing wears out quickly, the shaft should be inspected for roughness. If a machine shop is available, roughness may be eliminated from a shaft by a finishing cut to smooth the surface; otherwise, it may be necessary to replace the shaft.

Packing should be renewed at prescribed intervals, to prevent the packing from becoming hard and scoring the shaft. When packing is being replaced, make certain that there is a uniform thickness around the shaft. An excess of packing on one side of the shaft will cause shaft deflection and may even result in breakage. Stuffing boxes should be packed loosely and the packing gland set up lightly, allowing adequate leakage for cooling and lubrication.

There is less likelihood of POOR ALIGNMENT BETWEEN THE DRIVING AND DRIVEN MEMBERS of a hydraulic transmission if the wedges, shims, jacking screws, or adjusting setscrews are properly set and secured when connected units are installed. However, because of a casualty, misalignment may occur that will cause severe stress and strain on the coupling and connected parts. Excessive misalignment should be elimi-

nated as soon as possible by replacing any defective parts and readjusting the installed aligning devices. If this is not done, pins, bushings, and bearings will have to be replaced frequently.

Since there is no end play to either the A-end or the B-end shaft, flexible couplings are generally used in hydraulic transmissions. Such couplings permit satisfactory operation with a slight misalignment, without requiring frequent renewal of parts.

## Trouble Shooting

In attempting to locate the source of any trouble in an electrohydraulic system, remember that all troubles which occur will be in one of three categories—hydraulic, electric, or mechanical. Isolating a trouble into one of these categories is one of the primary steps in locating the source of trouble.

HYDRAULIC CASUALTIES. These casualties are generally the result of low oil levels, external or internal leakage, clogged lines or fittings, or improper adjustment of valves and other working parts. Do not disassemble a unit unless certain that the trouble exists within that unit. Unnecessary disassembly can lead to additional trouble, because of the dirt which may enter an open system.

Leaks are a frequent cause of trouble in hydraulic equipment. Leaks are generally caused by excessively worn parts, by abnormal and continuous vibration, by excessively high operating pressures, or by faulty or careless assembly. External leaks usually have little effect on the operation of equipment other than a steady draining of the oil supply; but even a small leak wastes oil, and the resulting unsightly appearance of a machine is indicative of poor maintenance procedures.

External leaks may result from any of the following causes: improperly tightened threaded fittings; crossed threads in fittings; improperly fitted or damaged gaskets; distorted or scored sealing rings, oil seals, or packing rings; scored surfaces of working parts; improperly flared tube ends; or flanged joints not seating squarely.

Internal leaks, however, generally result in unsatisfactory

operation of the equipment. Large internal leaks are indicated by loss of pressure and failure of equipment. While large internal leaks can usually be located by installing a pressure gage in various parts of the equipment, the location of small leaks generally requires disassembly and visual inspection of the parts. Internal leaks may result from worn or scored valves, pistons, valve plates, or bushings; or from improperly fitted or damaged gaskets.

The symptoms of trouble in a hydraulic system are frequently in the form of unusual noises. Some noises are characteristic of normal operation and can be disregarded, while others are evidence of serious trouble. Even though the exact sound indicating trouble can be learned only through practical experience, the following descriptive terms will give a general idea of the noises which are trouble warnings.

The occurrence of POPPING and SPUTTERING noises is an indication that air is entering the pump intake line. Air entering the system at this point may be the result of too small an intake pipe, an air leak in the suction line, a low oil level in the supply tank, cold or heavy oil, or possibly the use of improper oil.

If air becomes trapped in a hydraulic system, HAMMERING will occur in the equipment or in the transmission lines. If hammering occurs, check for improper venting. In some cases, a POUNDING or RATTLING noise occurs as a result of a partial vacuum produced in the active fluid during high-speed operation or when a heavy load is applied. This noise may be unavoidable under the conditions stated and can be overlooked if it stops when speed or load is reduced. If the noise continues at low speeds or light loads, the system should be vented of air. Air in a hydraulic system can also cause uneven motion of the B-end.

The cause of a GRINDING noise is most likely to be dry bearings, foreign matter in the oil, worn or scored parts, or overtightness of some adjustment.

The term HYDRAULIC CHATTER is sometimes used to identify noises caused by a vibrating spring-actuated valve, by long

pipes improperly secured, by air in the lines, or by binding of some part of the equipment.

If the packing is too tight around some moving part, SQUEALS or SQUEAKS may occur. This type of noise might also indicate that a high-frequency vibration is occurring in a relief valve.

ELECTRICAL CASUALTIES. Although the EM is responsible for checking electrical equipment troubles, the MM can facilitate maintenance of electrical equipment by making a few simple tests when electrical troubles occur. Such an oversight at not having a switch in the ON position may be the reason for equipment failing to operate. If the circuit is closed and the equipment still fails to operate, check for blown fuses and tripped circuit breakers. These troubles generally result from an overload on the equipment. If a circuit breaker continues to cut out, the trouble may be damaged equipment, excessive binding in the electric motor, obstruction in the hydraulic transmission lines, or faulty operation of the circuit breaker. Another source of electrical troubles may be in the circuit; check for open or shorted leads, faulty switches, and loose connections.

MECHANICAL CASUALTIES. When an electrohydraulically driven auxiliary becomes inoperative because of a mechanical failure, a check should be made for improper adjustment or misalignment of parts, shearing of pins or keys, or breakage of gearing, shafting, or linkage. Elimination of troubles resulting from any of these causes should be accomplished in accordance with the manufacturer's instructions for the specific equipment.

## COMPRESSED AIR SYSTEMS

As an MM3 or 2, you used compressed air for blowing out and cleaning various units, and for operating numerous pneumatic tools. In working with any of the three types of compressed air systems (low-, medium-, and high-pressure), you probably found that the primary source of any trouble was the compressor. Although the design and capacity of compressors vary, the maintenance procedures are essentially the

same. However, remember that the care and maintenance of high-pressure compressors require additional safety precautions, and the procedures recommended by the manufacturer should be followed.

Some portions of the discussion which follows may serve as a review. Other portions of the discussion should be beneficial in your study for advancement, and helpful when you are called upon to train men.

While modern auxiliary machinery is rugged and dependable, it is not designed to withstand abusive treatment. Gasketed joints, pipe joints, and bolts are designed to safely withstand the strain required for a tight connection when the specified torque is applied with the correct tool. The application of a force in excess of that prescribed usually results in breakage. If a joint or bolt cannot be tightened without using an oversized wrench or wrench handle extension, there will probably be something wrong with the assembly.

For example, in assembling newly designed high-pressure air compressors, extensive use is made of soft copper gaskets for sealing joints subject to pressures up to 3,000 psi. These gaskets make a tight and dependable seal if the joint is tightened down properly. However, as the tightening pressure is applied to the joint, the copper gasket is compressed and becomes work-hardened. Therefore, if the joint is broken and the gasket reused, a greater tightening force is required to make a tight seal. If wrench extensions are used, it is possible to distort the gasketed surface or twist off the boss without achieving a tight joint. Even though a correct wrench is used, acquiring additional force by pounding with a hammer usually results in damage to the equipment.

## Care and Maintenance of Air Compressors

The over-all problem in maintaining compressed air systems is to take the necessary steps to prevent a reduction in compressor capacity. Some of the common troubles which reduce compressor capacity, and the causes of these troubles, are as follows:

| Troubles | Causes |
|---|---|
| Overheating of air cylinders. | Operating the compressor at speeds in excess of recommended number of piston strokes/minute, or against excessive pressure. Such operation destroys lubrication, with resulting scoring of cylinders, abnormal noises, burned deposits in discharge passages, and over-all reduction in efficiency. |
| Air leaks | Defective air valves resulting from wear and pounding of valves against seats, and dirty intake air. |
| | Defective air cylinder stuffing box. |
| Groaning | Poorly lubricated air cylinders. |
| | Dry and binding piston rod packing. |
| | Leaking discharge valves. |
| | Loose air-piston rings. |
| Pounding | Loose air pistons. |
| | Loose reversing plate. |
| | Worn reversing mechanism. |
| | Loose holding-down bolts. |
| Uneven piston strokes | Dirty air valves. |
| | Improper lift of air valves. |
| | Leaking past air-piston rings. |
| | Clogged air passages. |
| | Binding or cutting of reversing rod. |

To keep a ship's air compressors operating efficiently at all times and to prevent as many troubles as possible, it is necessary to know how to care for air intakes and filters; how to maintain and replace air valves; how to take care of air cylinders, pistons, and wrist pins; how to adjust bearings, couplings, etc.; and how to properly maintain the lubrication, cooling, control, and air systems.

Air Intakes and Intake Filters. Satisfactory operation of any compressor requires a supply of clean, cool, dry air. To help keep the air supply clean, filters are fitted to compressor intakes. Unless these filters are inspected and cleaned regularly they will become clogged and cause a loss of capacity.

To clean filter elements remove them from the intake and wash them with a jet of hot water or steam, or immerse them in a strong solution of sal soda. The filter body should be drained and replaced. Filter elements of the oil-wetted type should be dipped in clean oil after cleaning. Before replacing the element in the intake, let excess oil drain from it. The use of gasoline or kerosene is prohibited for cleaning air filters, because of explosive fumes which may collect in the compressor or air receiver.

Air Valves. The inlet and discharge valves of compressors require special attention. When valves leak, compressor capacity is reduced and pressure is affected. Deviation from normal intercooler pressure may indicate a leaking or broken valve; rise in pressure indicates a defective inlet valve, decrease in pressure indicates a defective discharge valve. Another sign of valve trouble is an unusually hot valve cover.

Dirt is generally the cause of leaking valves. When valves become dirty, the source of trouble can usually be traced to dirty intake air; use of an excessive amount, or of an improper grade, of cylinder oil; or excessively high air temperature, resulting from faulty cooling. Periodic inspection and cleaning of valves and valve passages minimizes the number of air valve troubles.

When air valves are removed for inspection, mark each valve to ensure that it will be replaced in the same opening from which it was removed. Inspect valves carefully and do not disassemble them for cleaning unless their condition necessitates such action. Dirt or carbon can usually be removed from valve parts without disassembling the valve. If it becomes necessary to disassemble the valve, note the arrangement of the various parts so that the proper relationship will be kept when the valve is reassembled. To remove carbon from valve parts, soak the individual part in a suitable solvent and then brush or scrape lightly. After drying and reassembling the valve parts, test the operation of the valve to see if it opens and closes freely.

Before replacing air valves in a cylinder, inspect the gaskets and replace any which are damaged. Since it may

be difficult, in many cases, to distinguish between suction and discharge valves, extreme care must be taken when the valves are being inserted in the cylinder. Make certain that suction valves open TOWARD, and discharge valves AWAY FROM, the center of the cylinder; otherwise serious damage or loss of capacity will result. If special lock nuts are not provided to seal against leakage at the threads of the valve setscrew, a turn of solder or fuse wire should be placed around the screw and set down into a recess by the locking nut.

CYLINDERS, PISTONS, AND OTHER COMPONENT PARTS. You should be familiar with the safety precautions to be followed in maintaining an air compressor, and with the procedures for cleaning cylinders, removing pistons, fitting new piston rings, replacing cylinders, checking piston end clearances, adjusting bearings, replacing wrist pins, packing stuffing boxes, and caring for couplings and V-belts. It is essential, therefore, to consult the maintenance procedures as recommended by the manufacturer.

CONTROL DEVICES. Because of the great variety of control, regulating, and unloading devices used with compressors, detailed instructions on their adjustment and maintenance must be obtained from manufacturer's instruction books.

If a control valve fails to operate properly, disassembly and a thorough cleaning will usually be necessary. Some control valves are fitted with filters filled with sponge or woolen yarn, to prevent dust and grit from being carried into the valve chamber. These filters also remove the gummy deposit which comes from the oil used in the compressor cylinders. The filter element should be replaced with the specified material each time a valve is cleaned. Do not use cotton, because it will pack down and stop the air flow.

Since relief valves are necessary to ensure safe operation of a compressed air system, they must be maintained in satisfactory operating conditions at all times. Relief valves should be set as specified by the manufacturer. They should be tested by hand each time the compressor is started, and the valve setting should be checked periodically by raising the pressure in the spaces to which the valves are attached.

Lubricating and Cooling Systems. In the case of air-cooled compressors, steps must be taken to keep the cooling fins clean. Oil and dust are effective insulators; if they are allowed to collect on the fins, they will prevent heat transfer.

The lubricating system of a compressor should give little trouble if the following steps are taken:

1. Keep the reservoir oil at the prescribed level in order to maintain proper oil temperature.

2. Change the crankcase oil periodically, and at the same time flush the crankcase and clean the oil filter.

3. Maintain proper lube oil pressure by keeping the oil pump in good working condition and by adjusting the bypass relief valve.

4. Keep the oil cooler free from leaks, to prevent oil contamination and emulsification.

5. Replenish as necessary the glycerine and water in the lubricator sight feeds.

6. Keep the lubricator in proper adjustment for the specified quantity of oil feed.

For the compressor cooling system, general requirements for care and maintenance are as follows:

1. Periodic inspections should be made of intercoolers and aftercoolers.

2. Collections of gummy oils or tarry substances on the sides of cooler tubes should be removed by washing the tube nests with a cutting solution. Make certain that the tube nests are completely dry before reassembling them.

3. Leaks in the tube nests must be repaired; otherwise, water will leak into the compressor while it is secured, and air will leak into the water side during operation.

4. Cylinder water jackets should be inspected and cleaned periodically with a cleaning nozzle.

5. When a drained compressor water-cooling system is being filled, the water inlet valve should be opened slightly to allow the water to rise slowly in the cooler shell and water jackets. In addition, the vent valves fitted to the water spaces should be opened, so that entrapped air can escape and air pockets will not form in the system.

Surface Inspections and Maintenance. The air flasks, relay tanks, and separators of surface ships must be given a surface inspection every three months. These inspections are made to determine if there is any external corrosion or damage to flasks or piping. The results of such inspections should be entered in the Material History Record.

Because the internal surfaces of air flasks are coated with zinc chromate primer, corrosion seldom occurs there. On the external surfaces of air flasks, however, corrosion may be sufficiently serious to weaken the material—especially in high-pressure flasks. Such corrosion usually occurs at points which cannot easily be reached for cleaning and painting.

If no information is available in the instruction books, experience must be relied upon to determine how often air flasks, accumulators, relay tanks, separators, and piping must be drained. In any event, drainage of air system equipment must be sufficiently frequent to prevent excessive accumulations of moisture and oil. Such accumulations not only cause internal corrosion and fouling of moving parts, but also create a serious hazard in that excessive oil accumulation may cause an explosion.

Inspection, Cleaning, and Testing by Repair Activities. In addition to shipboard inspection and maintenance of high-pressure air flasks and separators, there must be an inspection, cleaning, and testing performed at prescribed intervals by a repair activity. For surface vessels the initial interval should not exceed six years; subsequent intervals should be approximately three years. However, if there is reason to believe that serious corrosion is taking place in either the exteriors or interiors of air flasks, inspection should be made before the elapse of the normal interval.

The periodic examinations should include not only a complete examination of the interior and exterior surfaces of flasks and separators, but a thorough cleaning also, and the performance of hydrostatic tests. Flasks which pass the

hydrostatic test are given the prescribed internal protective coating, and the exterior surfaces are painted if necessary. Detailed information on the inspections and maintenance performed by naval shipyards can be found in chapter 49 of BuShips *Manual*.

### Inspections and Tests

Minimum requirements for the performance of inspections and tests on compressed air plants are as follows:

| Time | Action |
|---|---|
| When starting compressor for first time, or starting end which has been idle for some time. | Inspect all intake and compressor control lines for obstructions and foreign matter. Inspect interior and exterior of compressor. |
| Before starting any compressor. | Jack over several times by hand. |
| After starting compressor | Test relief valves by hand.<br>Test operation of automatic controls. |
| At frequent intervals during compressor operation. | Test for excess lube oil by opening compressor separator and receiver drains.<br>Check instruments for signs of improper operation. |
| * * | * * * |
| Routine tests; record results on engineering log | |
| DAILY | Jack over all compressors by hand. |
| WEEKLY | Run compressors by power. |
| MONTHLY | Inspect all air inlet and discharge valves. |
| QUARTERLY | Measure starting and operating power of motor-driven compressors; if excessive, overhaul.<br>Make general inspection of all compressor parts; pull pistons and remove connecting rods only if cylinder conditions and other conditions indicate necessity.<br>Test operation and setting of speed-limiting and emergency overspeed tripping devices, if installed. |
| ANNUALLY | Test all parts of the air system under full pressure. |

| Time | Action |
|---|---|
| DURING NAVAL SHIPYARD OVERHAUL PERIOD | Disassemble and inspect compressor. Test all relief valves by pressure. Inspect interiors of air receivers. |
| AT PRESCRIBED INTERVALS | Test hydrostatically, at 1½ times the designed working pressure, all low- and medium-pressure air accumulators or receivers. |
| AT DISCRETION OF ENGINEER OFFICER. | Test capacity of compressors. |

It is the responsibility of the engineer officer to determine if the condition of the equipment, hours of service, or operating conditions necessitate more frequent inspections and tests. Details for outline tests and inspections may be obtained from the appropriate manufacturer's instruction book or from chapter 49 of BuShips *Manual.*

### Safety Precautions

Peak operating performance from a compressed air plant requires that steps be taken to prevent or minimize the occurrence of casualties which may reduce plant capacity or result in serious damage. Explosions are a potential hazard, especially in high-pressure systems, and personnel should take every possible precaution to prevent them. To help prevent explosions and to maintain a compressed air plant in satisfactory operating condition, the following safety precautions should be observed:

1. Minimize the possibility of explosions in an air compressor, discharge line, or receiver by taking appropriate steps to prevent or eliminate:
   a. Dust-laden intake air.
   b. Presence of oil vapor in compressor or receiver.
   c. Leaking or dirty valves which result in abnormally high temperatures.
2. See that the compressor intake receives only cool, clean, dry air.

3. Use only prescribed agents for cleaning compressor intake filters, cylinders, or air passages. Do NOT use benzine, kerosene, or other light oils that vaporize easily and that, under compression, form a highly explosive mixture with air.
4. Use only the minimum amount and the proper grade of oil for cylinder lubrication.
5. Secure a compressor immediately if there is an abnormal rise in the temperature of air discharged from any stage.
6. Make sure that a relief valve is installed between a compressor and a stop valve or check valve, if either of the latter valves is installed between a compressor and receiver. Otherwise, if the compressor is started against a closed valve or a deranged check valve, the air cannot escape and an explosion will result.
7. Never leave a compression station after starting a compressor—especially one that is new, or one that has been idle for some time—without making certain that control, unloading, and governing devices are functioning properly.
8. Do not disconnect any part of a compressor if the system is under pressure. Serious accidents can be avoided if the following precautions are taken before servicing or removing any part of a compressor:
    a. Leave pressure gages open.
    b. See that the compressor is actually secured and cannot be started automatically or accidentally.
    c. See that the compressor is completely blown down.
    d. See that all valves, including the control or unloading valves, between the compressor and receiver are closed.
9. Prevent damage from excessive temperatures by operating a compressor at recommended speeds and maintaining proper cooling-water circulation.
10. Drain the circulating water system of a compressor if it is to remain idle for any length of time, or if it is to be exposed to freezing temperature.

# STEAM WHISTLES AND SIRENS

Since you may have to supervise the maintenance and repair of steam whistles and sirens installed on your ship, you should be familiar with the installation and maintenance of these units.

## Steam Whistle

The diaphragm type of steam whistle is typical of the type used on modern ships. Before testing or operating the whistle, remove the diaphragm leaves by unscrewing the back cover, and turn on the steam at least 30 minutes, with all drains open and traps operating. With the diaphragm removed, operate the whistle valve several times in order to blow out the pipe lines thoroughly. Replace the proper number of leaves and tighten the back cover before testing. The leaves are marked so that they may be installed properly; all leaves must have the high side facing towards the nozzle.

If water comes out through the horn or around the stem of the operating valve while the whistle is being tested, or if the note is not clear from the beginning of the first blast, immediately check all associated traps. If the traps are not functioning properly, they should be bypassed until put into working order.

The diaphragm of a steam whistle must be inspected and cleaned every three months. Damaged leaves must be removed and replaced. After the leaves have been cleaned and positioned properly, the whistle must be retested.

The operating valve should also be checked when the diaphragm is examined. If the operating valve is leaking, it should be removed and ground in to obtain a good clean seat. The seat is generally locked in place with a setscrew and can be removed only with a proper wrench and after the setscrew has been loosened.

## Steam Siren

The steam siren is a more effective sound-producing device than the steam whistle. It is operated by auxiliary steam, which enters through a control valve and fills an annular

chamber surrounding a stationary slotted cylinder. The best tone is obtained by a gradual opening and closing of the operating valve.

In order to prevent damage to the siren by water hammer and erosion, the steam line supplying the siren must be kept constantly drained and must contain a water separator.

### Whistle and Siren Piping Systems

On the installation of a whistle valve, the following factors should be considered:

1. Steam supply must be taken either directly from a boiler or from a point on a steam line where there is a continuous flow of steam at all times.
2. There must be no horizontal piping between the whistle and the point where the steam supply line is connected.
3. A drain must be installed at the lowest point of a long lead of piping below decks.
4. The drain line from the whistle must be connected to a continuous flow trap connected to the atmosphere (never to the high-pressure drains).

When installing a siren unit, the following factors should be considered:

1. The siren should be installed as near a vertical position as possible.
2. The air or steam lines should be thoroughly blown out and cleaned of sediment, scale, etc., before they are connected.

## AUXILIARY BOILERS

On Diesel-driven ships, steam for distilling plants, space heating, oil heating, water heating, galley, and laundry is supplied by small boilers known as auxiliary boilers. These boilers are equipped with all auxiliaries, accessories, and controls to effect a unit assembly and are arranged to operate as complete and self-contained steam generating plants. Because of this distinctive arrangement, these boilers are called by their manufacturers "steam generating units" and "steam generators."

## Types of Boilers

Auxiliary boilers aboard Navy ships may be divided into two groups: Water tube type boilers and fire tube boilers. Boilers of the water-tube type are further classified as natural-circulation boilers and forced-circulation boilers.

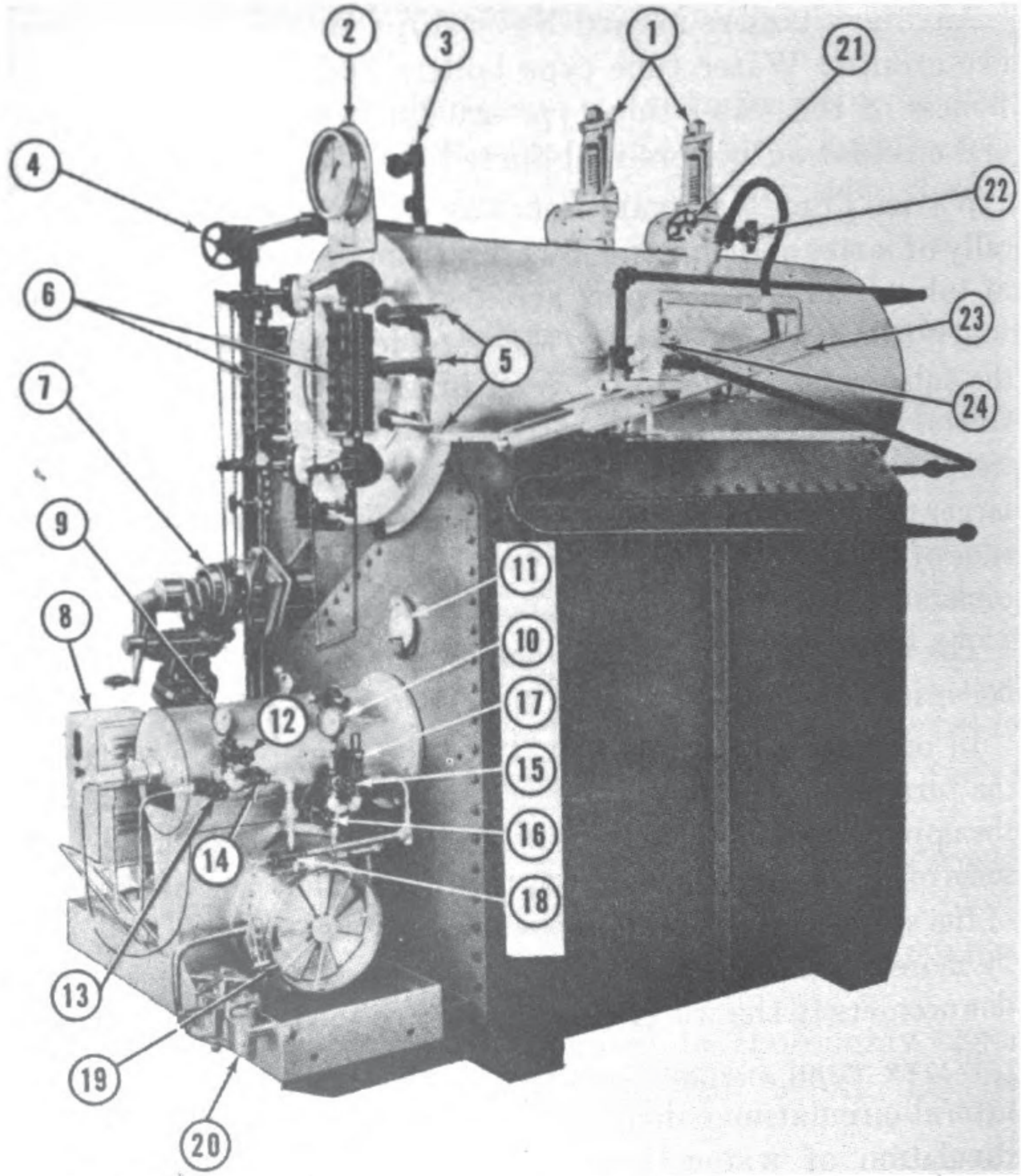
WATER TUBE NATURAL-CIRCULATION BOILERS consist basically of a steam drum and a water drum connected by a bank of tubes. The two drums are also connected by a row of water tubes which form a water-cooled side wall opposite the tube bank. The water wall tubes pass beneath the refractory furnace floor before they enter the water drum. The steam and water drums may also be connected by several larger tubes, called downcomers, located at the front and rear ends of the boiler. Refractory is used to protect these downcomers from contact with the combustion gases.

The assembly of a typical water tube natural-circulation boiler is shown in figure 15–1.

In operation, the water in the tubes receives heat from the furnace gases, and becomes less dense and flows toward the upper end of the tubes. Before reaching the steam drum some of the water forms steam bubbles, which rise to the top of the steam drum. The hot water and steam are displaced by more of the relatively cool water flowing through the downcomers to the water drum, and into the tubes.

WATER TUBE FORCED-CIRCULATION BOILERS differ from the natural-circulation chiefly in the fact that there is continuous circulation of water through coils which may be located above, or form a part of, the combustion space. The hot water from these coils is discharged into the chamber, where part of the water flashes into steam. The steam accumulates in the upper portion of the chamber and the unevaporated water collects in the lower portion. The water is recirculated back to the heating coil or water tank. (See chapter 51 of BuShips *Manual.*)

FIRE TUBE BOILERS are generally similar to Scotch marine or locomotive boilers. In this type of boiler the gases of




1. Safety Valves
2. Steam Pressure Gage
3. Vent Valve
4. Soot Blower Steam Valve
5. Boiler Gage Cocks
6. Water Gages
7. Soot Blower
8. Motor Control
9. Oil Return Pressure Gage
10. Oil Supply Pressure Gage
11. Peep Door
12. Oil Return Pressure Gage Valve
13. Oil Return Valve
14. Oil Return Check Valve
15. Oil Supply Pressure Gage Valve
16. Oil Supply Valve
17. Oil Regulating Relief Valve
18. Oil Control Metering Valve
19. Air Vortex Control
20. Fuel Oil Filter
21. Feedwater Regulator Steam Shut-Off Valve
22. Cleaning Connection
23. Feedwater Regulator
24. Feedwater Regulator Control Valve

**Figure 15–1.—Water tube, natural-circulation boiler.**

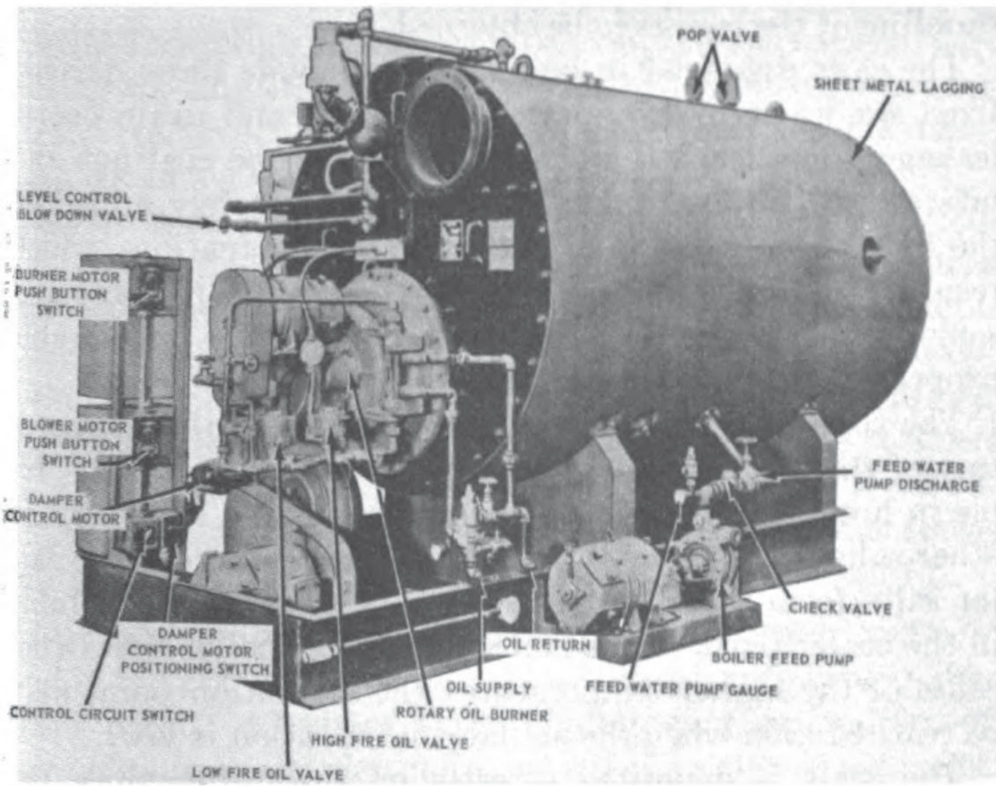



**Figure 15–2.—Fire tube auxiliary boiler.**

combustion pass through tubes that are surrounded by water. Figure 15–2 illustrates a typical unit.

### Boiler Water Requirements

In order for an auxiliary boiler to function properly, steps must be taken to prevent scale formation on the water side of the boiler, to reduce corrosion of the boiler metal to a minimum, and to ensure the absence of foaming and priming under all operating conditions. Therefore, it is necessary to prepare and maintain the feed water in the purest possible condition, to chemically treat the boiler water in order to maintain its composition in a desirable range, and to periodically inspect and clean the water sides.

PREVENTION OF SCALE FORMATION. All water contains some salts in solution; therefore, it is essential to treat boiler water and boiler feed water to counteract any undesirable results of such solution. Using chemicals or water-treating compounds indiscriminately, however, will not guarantee the

desired results. It is very important to possess an understanding of the results to be obtained.

The salts dissolved in boiler water include those derived from sea water by evaporator carry-over and drain cooler leakage, those leached and dissolved from the coatings and interiors of piping and tanks, those deliberately added in the boiler compound, and the various combinations which result from this mixture. Some of these salts are corrosive, some are scale forming, and some combat the undesirable properties of the first two classes.

The solubility of salts in water varies with the temperature of the water solution. Some salts are much more soluble in hot water than in cold water, while the solubility of other salts decreases with increasing temperature. The latter salts form scale. These salts may be relatively soluble in the cooler parts of the boiler, but in the boiler tubes (because of the higher temperature) the saturation point may be reached even when the actual concentration is low.

The scale is deposited directly on the metal, since the hottest water is that which is in contact with the metal surface. When a bubble of steam is formed on the evaporative surface, the salts contained in the water from which the steam was formed are forced (since salts do not evaporate) into the envelope of water closely surrounding the bubble. Where the steam bubble, the water, and the tube surface make contact with each other, an irregular circular line is formed on the metal surface. The scale-forming salts will be deposited on this line of contact, because this will be the hottest part of the system. In this area not only will the solubility of the scale-forming salts be the lowest, but the amounts present will be a maximum. As the bubble leaves the metal surface, a ring of small scale crystals will be left to mark the location where the bubble formed. As evaporation proceeds, the many rings of scale crystals become interlaced and the individual crystals increase in size.

Tube failures resulted from scale formation. Furnace temperatures are much higher than can be withstood by uncooled tubes. A layer of scale on the tube surface prevents normal

heat transfer through the tube wall to the boiler water, thereby increasing the temperature of the tube metal and causing wasting away on the fire side by oxidation. A very slight layer of scale is sufficient to raise the tube wall temperature enough to cause failure.

Boiler scale prevention is a relatively simple matter; it involves adding to the water one or more highly soluble chemicals, such as sodium carbonate or sodium phosphate. Navy BOILER COMPOUND includes scale-preventing chemicals.

Boiler compound should be added, as necessary, to the boiler water to maintain zero hardness and alkalinity between 2.5 and 3.5 epm at all times. Daily tests should be made and only enough compound added to maintain the above limits, as too high or too low alkalinity are both harmful.

LIMITATIONS OF SHORE WATER. If shore water must be used in boilers, it first has to be evaporated in the ship's distilling plant. All shore waters contain varying amounts of contaminating salts, depending on the character of the rocks, sand, and earth over which they have flowed and on the extent and nature of municipal treatment to which they have been subjected. These impurities are different from those of boiler feed water, and cannot be controlled by the usual water-treatment methods.

If, in an emergency, it becomes necessary to use shore water which has not been evaporated in the ship's distilling plant, the water should be tested and only a neutral water, low in hardness, should be accepted for temporary use. A neutral water is one which is colorless with phenolphthalein indicator and green with methyl-purple indicator.

INSPECTION OF DRAIN RETURN LINES. These lines should be inspected for leaks and properly maintained in order to reduce the amount of make-up feed needed. The salt-water piping in the drain cooler should be checked frequently for leaks; since a leak in this piping allows sea water to mix with the drains, and the result is contamination of the boiler water in a very short time.

Water samples to be analyzed should be free from suspended matter and protected from contamination during the interval between sampling and analysis.

Fresh water is generally free from suspended matter, but should be collected in bottles which can be stoppered to avoid contamination by the air. Unless the sample bottle is not tightly stoppered, the alkaline sample will absorb carbon dioxide from the air, reconverting the hydroxide to carbonate. In such a case, erroneously low results for alkalinity will be obtained with the phenolphthalein titration.

When samples of water are to be taken for analysis, the sampling connection must first be thoroughly flushed out. This will serve to remove any sediment which may be trapped in the connection, and it will ensure that the samples are truly representative of the water in the boiler.

ALKALINITY. The alkalinity content of water from steaming boilers may be determined by the following procedure:

Obtain a filtered and cooled sample of the boiler water from the specially fitted salinity cocks on each boiler to be tested. (Take approximately one-half cup in a container numbered for easy identification.)

Transfer 50 milliliters (ml) of the water to be tested into a clean, well-dried porcelain casserole, using a 50-ml pipette previously rinsed in test water.

Add two or three drops of the phenolphthalein indicator. This will give the sample a deep pink color if the water is alkaline.

Fill the automatic-zero burette with nitric acid solution (0.05N), and let it drain down to zero.

Add the acid solution from the burette while stirring the sample continuously. As the color begins to fade, add the solution a drop at a time and continue until the pink color disappears.

Read the burette in milliliters, which will equal the alkalinity of the sample in equivalents per million. For example: A burette reading of 2.6 ml represents an alkalinity of 2.6 epm.

HARDNESS. The hardness of water evaporated from sea water and from boilers fed with such water is determined by the following procedure:

Transfer 50 ml of water sample in an 8-ounce bottle with pipette.

Fill the burette with soap solution and let it drain down to zero. The amount of soap solution required to produce lather in pure water (LATHER FACTOR) has been determined and is marked on the bottle.

Add to the sample an amount of soap equal to the lather factor; stopper the bottle and shake it vigorously.

Lay the bottle on its side and start a stop watch.

If the lather persists and completely covers the surface of the water for 5 minutes, report ZERO HARDNESS.

If the lather does not persist, add an additional amount of soap solution equal to the lather factor, stopper the bottle, shake vigorously, and time the lather.

Repeat until a lather is obtained which completely covers the surface of the water for 5 minutes.

Read the burette and subtract the lather factor from this reading. (The lather factor of a soap solution is the amount of the solution required to form a lather on a sample of pure water. It should be determined for each new lot of reagent soap solution as soon as a full bottle has been made up.)

The burette reading minus the lather factor and multipled by 0.2 equals the hardness of the sample in epm. For example: If the titration is 0.30 ml and the lather factor of the reagent soap solution used is 0.10 ml, the hardness of the sample is 0.04 epm: $(0.30-0.10)\times 0.2=0.04$.

CHLORIDE. The procedure for the chloride test is as follows:

1. Add 5 drops of chloride indicator (diphenylcarbazone-bromo-phenol blue) to 25 ml of boiler water in a white porcelain casserole. The water will then turn blue-violet or red, depending on the degree of its alkalinity.
2. Add 0.05 N nitric acid, one drop at a time, until the blue-violet or red color changes to a pale yellow; then add 1 ml excess of nitric acid.

3. Add reagent mercuric nitrate solution (0.025 N) from the burette, continuously stirring the solution, until the pale yellow of the sample disappears and a pale blue-violet color persists throughout. The rate at which mercuric nitrate is added should be reasonably constant during the early part of the titration, then reduced to separate drops as the end point (blue-violet color) is approached.

4. Read the burette. The burette reading in milliliters equals the chloride content of the sample in epm. If the chloride concentration exceeds 20 epm, it will be more convenient to use a correspondingly smaller sample of boiler water rather than to refill the burette repeatedly. In such a case, dilute the smaller sample to 25 ml, in the graduated cylinder, with distilled water and mix well. The chloride concentration of the original sample can then be calculated as follows:

$$\frac{\text{Burette reading (ml)} \times 25}{\text{Volume of solution diluted (ml)}} = \text{epm of chloride}$$

For example, if a 5-ml sample is diluted to 25 ml, and the burette reading is 10 ml, then the chloride content is calculated as follows:

$$\frac{10\text{ ml} \times 25}{5\text{ ml}} = 50\text{ epm}$$

The chloride test should be made daily on steaming boilers and the concentration should not be allowed to exceed 15 epm in water-tube auxiliary boilers and 50 epm in fire-tube auxiliary boilers. When concentrations exceed this limit, the boiler should be blown down or secured, dumped, flushed, and refilled.

Make-up feed water should not be used when the chloride content is greater than 0.5 epm.

## Oil Burners

Oil burners used on auxiliary boilers are of the mechanical atomizing type. Most burners are equipped with pressure type atomizers; however, a few atomizers of the rotary cup

type are in use. Two of the types commonly used are the constant capacity and the variable capacity pressure atomizing burners.

CONSTANT CAPACITY PRESSURE ATOMIZING BURNERS. Burners of this type are arranged for electric ignition and automatic control. Basically these burners consist of a burner cone or plenum chamber, connected to the fan casing; bracket for nozzle and electrodes; and oil atomizing nozzle. Variation of boiler load with this type of burner is accomplished by means of the automatic "off and on" cycling of the burner. Burners intended to meet wide variation of boiler steaming loads are designed with dual or triple nozzle arrangements in order to eliminate excessive cycling. In such cases one nozzle is used as a pilot and additional nozzles are manually cut in as required. Standard commercial nozzles are used with burners of this type.

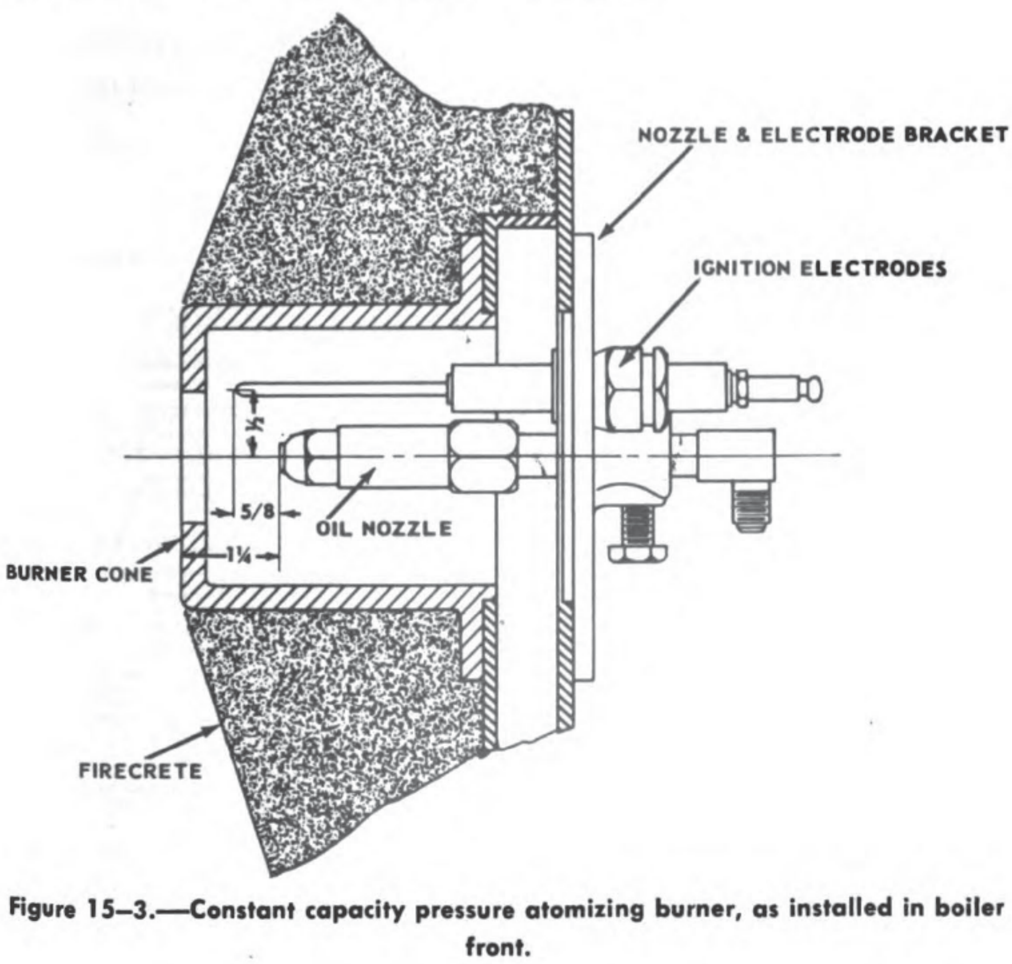



**Figure 15–3.—Constant capacity pressure atomizing burner, as installed in boiler front.**

A typical arrangement of a burner and construction of the oil-atomizing nozzle are shown in figures 15–3 and 15–4, respectively.

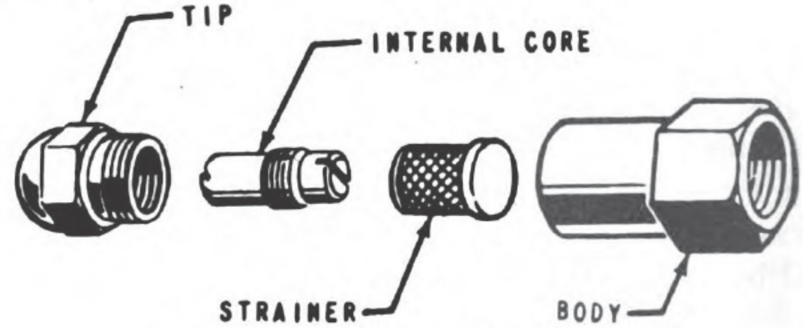



Figure 15–4.—Burner nozzle disassembled.

Variable Capacity Pressure Atomizing Burners. The atomizing unit of these burners consists of a burner barrel, nozzle body or distributor, sprayer plate, orifice plate, and atomizer nut. The capacity of these atomizers is regulated by means of an oil control valve placed in the oil return line. While supply of oil to the atomizer is kept at a constant rate

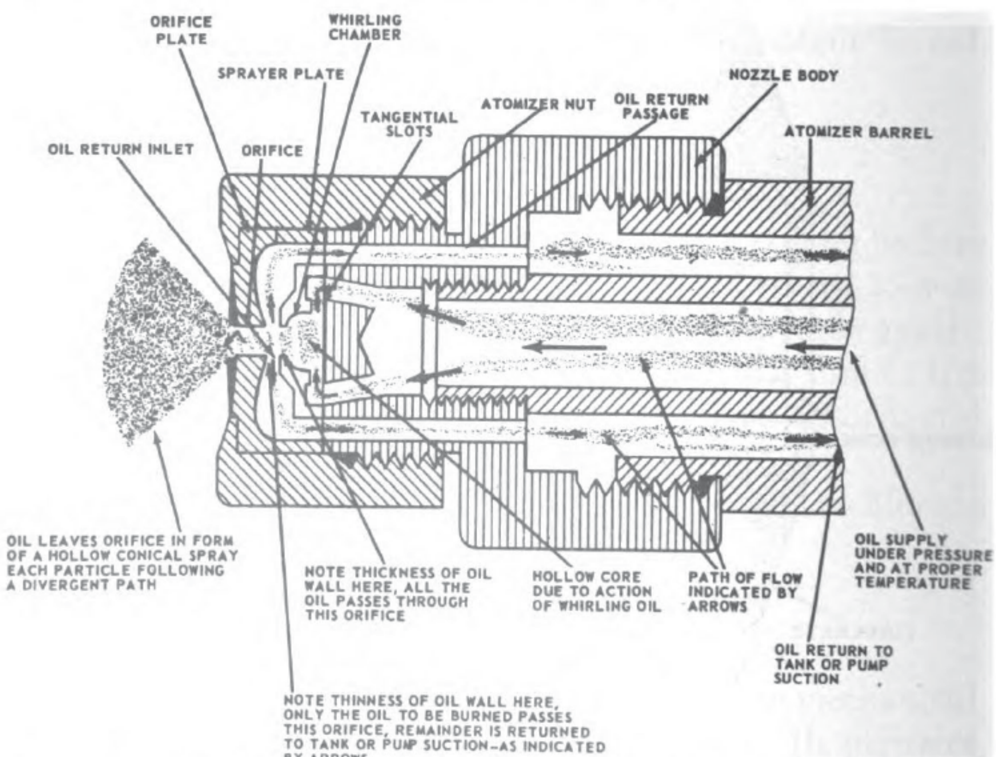



Figure 15–5.—Variable capacity pressure atomizing burner, showing oil flow.

of flow and a constant pressure necessary for proper atomization, amounts of oil returned from the atomizer may be varied by increasing or decreasing pressure at the oil control valve. The amount of oil atomized is always the difference between oil supplied to and oil returned from the atomizer. An oil-metering valve is linked with a mechanism regulating air admission to the burner, so that air and oil may be properly proportioned over the entire range of burner operation. Typical construction of this type of atomizer is illustrated in figure 15–5.

### Boiler Controls

The operation of auxiliary boilers may be accomplished manually, semiautomatically, or automatically. Controls installed on auxiliary boilers depend on the method of operation; in general, they may be classified as follows:

THERMOMECHANICAL FEED WATER REGULATORS are used on water tube, natural-circulation boilers.

FLOAT TYPE FEED WATER REGULATING AND LOW WATER CUT-OFF CONTROLS consist of a float chamber, a float, and a switch. The float chamber is connected to the boiler drum so that the water level in the chamber is always the same as the water level in the drum. The float is interlinked with a switch which is wired into the FEED PUMP CONTROL CIRCUIT. The switch contacts are open when the water level in drum and float chamber is normal. A drop in water level causes the switch contacts to close. This starts the feed pump. When the water level is restored to a predetermined high position, the switch breaks the contact and stops the feed pump. The low water cut-off feature consists of an additional switch, mounted in the same case as the pump switch, but wired into the BURNER CIRCUIT. If the water level drops below a permissible minimum, the low water cut-off switch breaks the burner circuit and stops the burner.

ELECTRODE TYPE FEED WATER REGULATING AND LOW WATER CUT-OFF CONTROLS consist of an electrode assembly and a water level relay. The electrode assembly contains three electrodes of different lengths, corresponding to high, low, and cut-off water level in the boiler drum. A typical electrode assembly is illustrated in figure 15–6.

The electrode assembly is installed on the top of the boiler drum so that the normal water level is at approximately the midpoint between the high-level and the low-level electrodes. The electrodes are electrically wired to the water level relay assembly. The relay contains the feed water pump start and stop contacts wired to the feed water pump controller, and the low water cut-off contacts wired into the burner circuit. The feed pump is started when the water level in the boiler drops below the middle electrode. After the water level is restored and reaches the high-level electrode, the feed pump is stopped. In case the water level is not restored

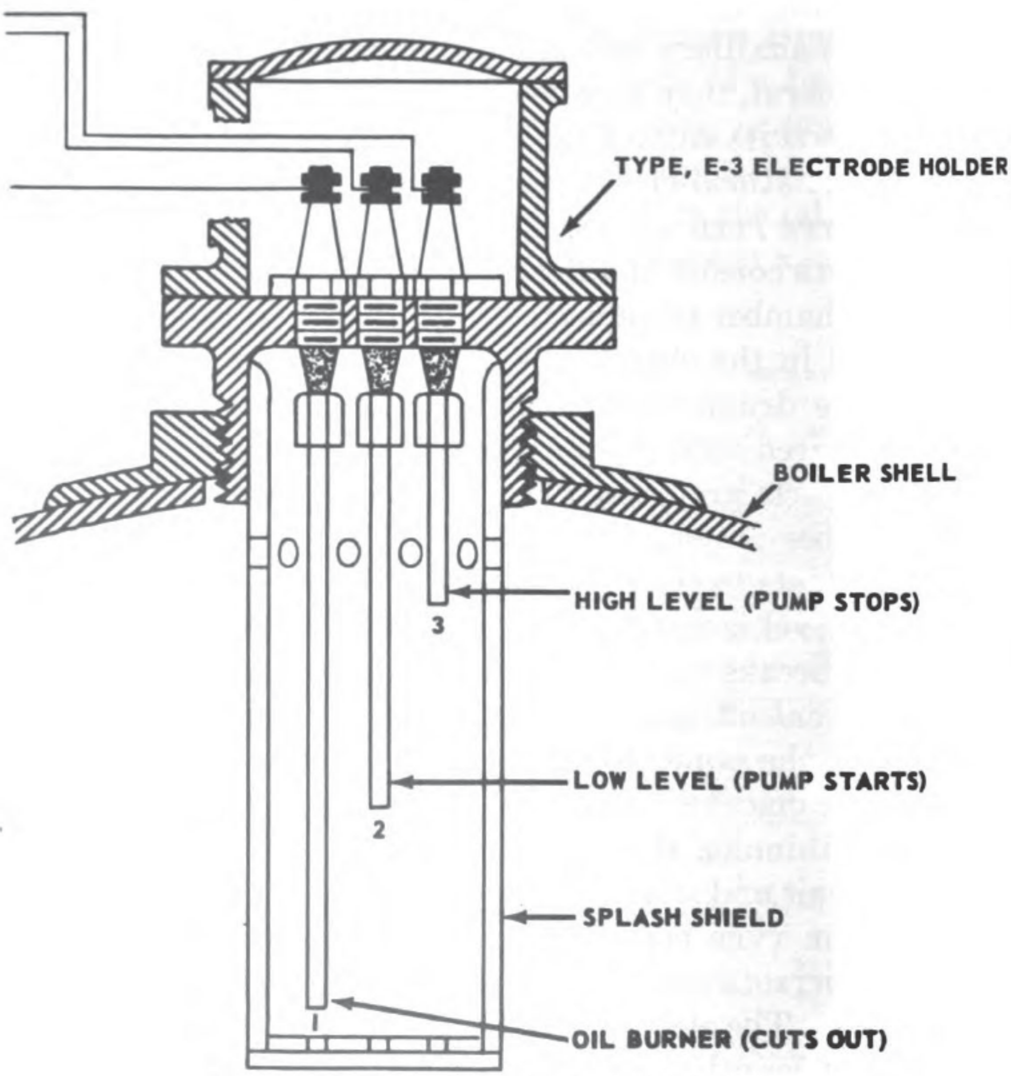



Figure 15–6.—Water-level electrode assembly.

and drops below the longest electrode, the cut-off contacts of the water level relay stop the burner by breaking the burner circuit.

The float type and the electrode type feed water regulating and low water controls are chiefly used on fire tube type boilers arranged for semiautomatic or automatic operation.

LIMIT PRESSURE SWITCHES AND PRESSURETROLS are pressure-operated switches designed to control burner operation within a fixed range of boiler pressures. Basically they consist of a bellows assembly linked with a snap switch through a pressure-adjusting mechanism. The bellows assembly expands or contracts with an increase or decrease of boiler pressure and causes the snap switch to open or close its contacts. The pressure-adjusting mechanism is set to permit opening and closing of the contacts at definite cut-out and cut-in boiler pressures. The differential between the cut-out and cut-in pressures may be either adjustable or fixed.

On boilers adjusted for automatic operation the snap switch is wired into the burner electric circuit so that it will break the circuit and stop the burner when the cut-off pressure is reached, and will make the circuit and restart the burner when the boiler pressure falls below the cut-in pressure.

On boilers arranged for semiautomatic operation (manual ignition) the snap switch is wired into the burner circuit so that it will break the circuit at the cut-off pressure and will hold it open, preventing manual restart of the burner until pressure falls below cut-in setting.

A typical pressure switch arrangement is shown in figure 15–7.

MODULATING PRESSURETROLS are steam-operated rheostat switches used to automatically regulate the admission of oil and air to the burners. These switches are similar in design to limit pressuretrols, except that they are equipped with a potentiometer coil. The switch is wired into the circuit of a reversible motor which operates the linkage of the air-oil ratio adjusting mechanism. When boiler pressure increases or decreases with variation of the boiler load, the bellows

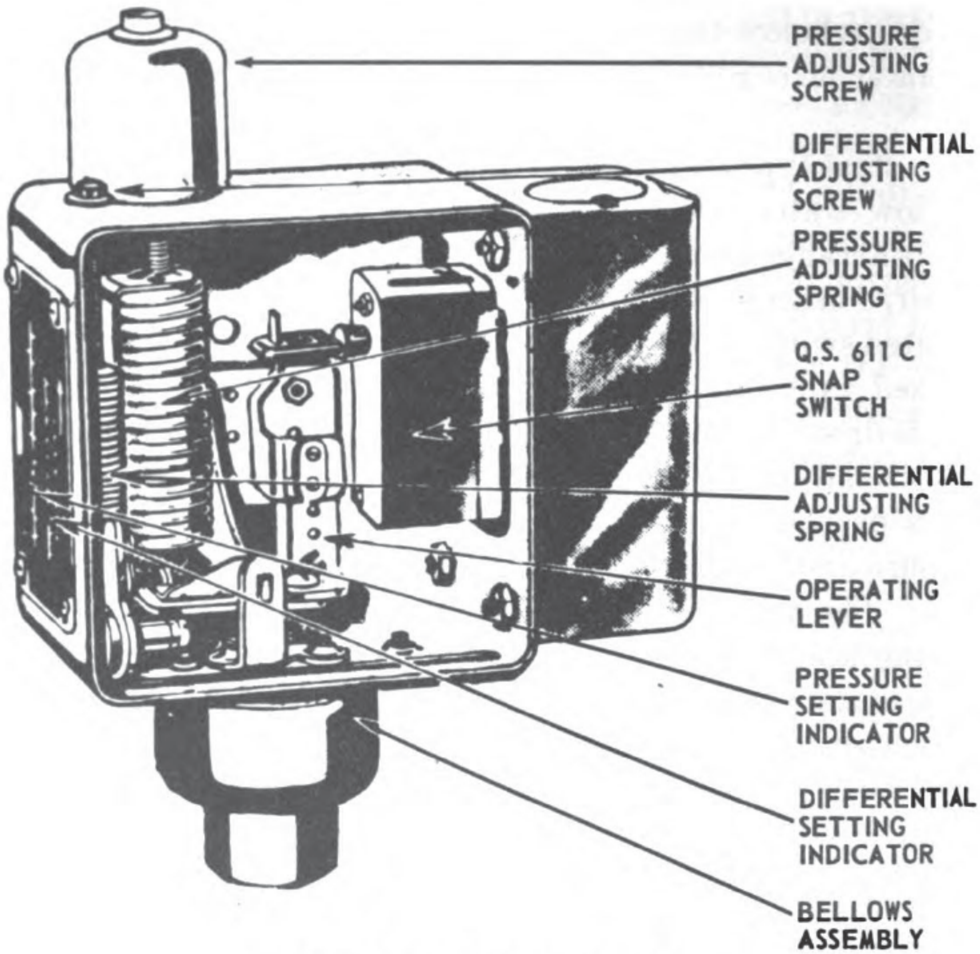



**Figure 15–7.—Pressure switch.**

assembly of the switch expands or contracts, thus causing a sliding contact to move across the potentiometer coil. The change in electrical balance of the motor circuit causes the motor to rotate, assuming positions necessary to rebalance the circuit. The movement of the motor, transmitted by means of a crank arm to the linkage between the fuel-metering valve and the damper air vanes, resets the oil-metering valve and the damper to positions corresponding to the firing rate required by the boiler load.

## Safety Combustion Controls

Safety combustion controls are devices designed to shut down the burner. In the event of ignition failure, or of flame failure subsequent to initial ignition, these devices

prevent flooding of the furnace. These controls are of either thermostatic type (stack switches and pyrostats) or photoelectric type.

STACK SWITCHES AND PYROSTATS are mounted on the boiler smoke pipe or hood. This type of control consists of a bimetallic helix, a mounting frame, a shaft carrying a contact-making mechanism, and an electric switch. The helix protrudes into the path of the combustion gases. The switch is wired into the burner electric circuit so that, when the contacts are open, no current is supplied to the burner except through the Protectorelay (to permit initial ignition). When there is no heat in the boiler, the switch contacts are open. When the burner is ignited, the increase of the stack temperature causes the helix to expand, and this expansion in turn causes the shaft to rotate and close the contacts. Unless the stack temperature decreases, the contacts will remain closed,

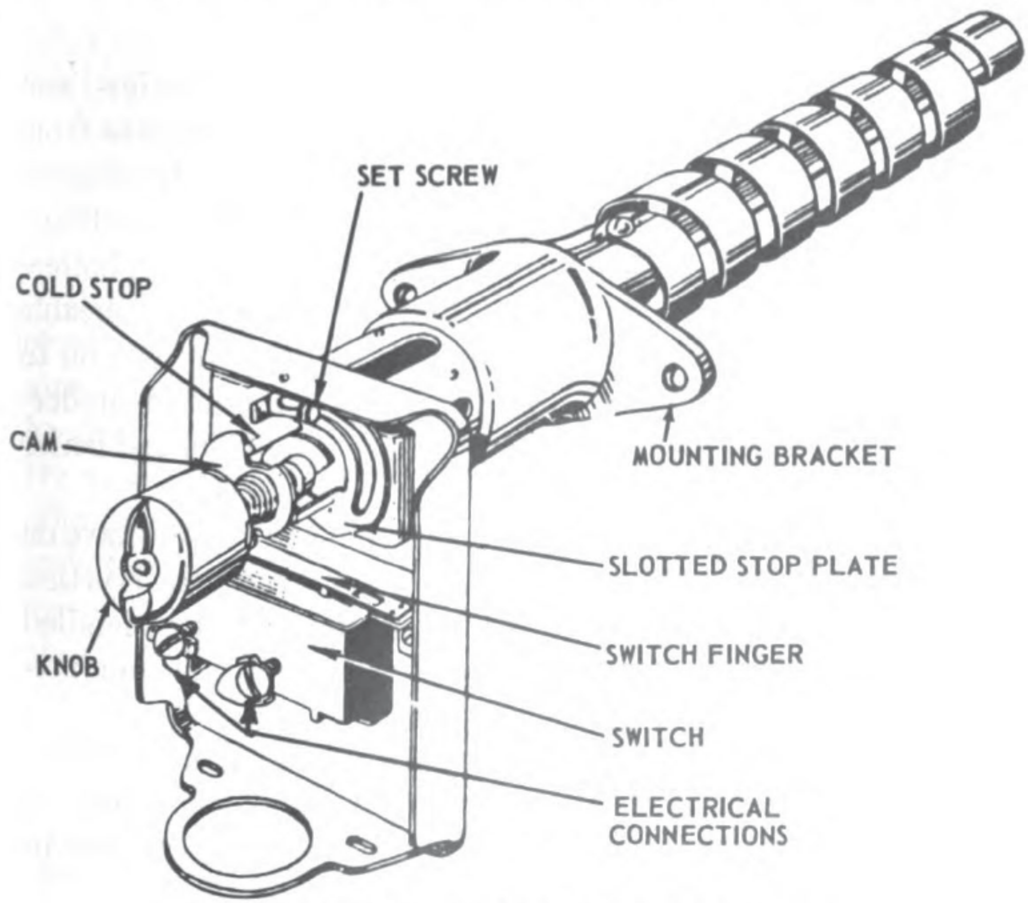



Figure 15–8.—Construction details of a pyrostat.

permitting operation of the burner. In the event of flame failure, the helix contracts as the stack temperature falls, and causes the shaft to rotate in the reverse direction. This opens the contacts and shuts down the burner.

Typical construction of a pyrostat is shown in figure 15–8.

PHOTOELECTRIC SAFETY COMBUSTION CONTROLS consist basically of photoelectric cell, amplifying unit, and relay. These controls operate by the luminosity of the flame acting upon the photoelectric cell. The latter makes a contact within itself when light rays impinge upon it. The amplified current of the photoelectric cell operates the relay, which is wired into the burner control circuit, causing the relay to close the burner circuit when the flame is established and to break the burner circuit in the event of flame failure.

### Use of BuShips *Manual* and Manufacturers' Instruction Books

Design and methods of operation of auxiliary boilers, and their accessories and controls, differ in various degrees from those of usual types of ship propulsion boilers. In chapter 51 of BuShips *Manual*, section VII is devoted to auxiliary boilers, but sections I through VI deal primarily with boilers used as main propulsion units, and are not wholly applicable to auxiliary boilers. However, it will be helpful for you to read this entire chapter, since it affords a thorough understanding of the principles of combustion, of shipboard boiler maintenance practices, and of safety precautions.

Every ship equipped with auxiliary boilers should have on board at least two copies of the manufacturer's instruction books. These instruction books should be used for detailed information regarding construction, operation, and maintenance.

Personnel charged with the operation of auxiliary boilers should also familiarize themselves with the principles of boiler feed water treatment and water tests, as covered in chapter 56 (section I) of BuShips *Manual*.

## SUMMARY

Because of the wide application of hydraulics throughout the modern ship, it is most important that those responsible for care and maintenance be thoroughly familiar with the machines using this method of power transmission. In many cases, the MM1 or C may be required to maintain auxiliary machinery equipped with a hydraulic system. You should know not only the construction and operating principles of the unit but also the proper procedures for its care and maintenance. Know what may cause trouble in a hydraulic system and what steps should be taken to eliminate the cause and prevent recurrence. Be familiar with the symptoms which are indicative of impending troubles and know what to do when such symptoms occur. Keep in mind that hydraulically operated equipment can usually be maintained in satisfactory operating condition by regular operation, by adequate and proper lubrication, and by maintenance of all units, as well as the working fluid, in the required state of cleanliness. Most casualties can be avoided if the prescribed instructions on operation, care, and maintenance are followed.

In the case of compressed air plants, maintenance is of paramount importance. Even when rigid procedures are followed, a reduction in plant capacity may result from several causes. The MM1 or C should be thoroughly familiar with the troubles which may occur, their causes, and the corrective action to be taken. It is necessary to have not only a thorough knowledge of written instructions, but also practical experience in maintaining all the components of a compressed air plant. This should include the care of air intakes and filters; the maintenance and repair of air valves, and of compressor air cylinders, pistons, and wrist pins; the adjustment of bearings and couplings; and the proper maintenance of the various systems in the plant.

Personnel charged with the operation of an auxiliary boiler should be thoroughly familiar with the boiler and all equipment installed thereon. Satisfactory operation of the

boiler depends on proper care and carrying out of maintenance procedures prescribed in the manufacturer's instruction book. Automatic regulating and control devices are designed to perform certain functions which otherwise would require attendance of additional personnel; therefore, specific attention should be given to maintaining these devices in proper operating condition. If failure of an automatic device remains undetected, damage to the equipment or injury to personnel may result.

## QUIZ

1. What are two important characteristics of a good hydraulic fluid?
2. When the charging tank of a telemotor hydraulic system is being filled, why is the fluid strained through cheesecloth?
3. How often should the ropes of the wire-rope type of remote control be removed and inspected?
4. What measures can be taken to protect the exposed portions of the hydraulic rams of a steering gear?
5. How often should the oil in the high-pressure hydraulic system of a steering gear be filtered?
6. What condition, other than wear, generally makes frequent adjustment of windlass brakes necessary?
7. The over-all efficiency of hydraulic installations used to drive auxiliary machinery is basically dependent upon what four factors?
8. What are the principal requirements necessary to maintain hydraulic gear in satisfactory operating condition?
9. Why should hydraulic equipment be operated at regular intervals?
10. What are two symptoms which signify that the shuttle valves of a hydraulic system are not operating properly?
11. During the cleaning procedure of a fluid system, what precautionary measures should be taken while a hydraulic unit is in operation?
12. What is likely to occur if the stuffing box packing of a hydraulic pump is not renewed regularly?
13. What are the four possible sources of trouble that result in hydraulic system casualties?
14. In brief, what is the difference in the processes used to locate large and small internal leaks in a hydraulic system?
15. If the capacity of an air compressor decreases because of air leaks, what are two possible causes of the trouble?
16. If a compressor begins to "groan," and reduction in capacity is indicated, what are the probable causes of this trouble?

17. Why should gasoline or kerosene never be used to clean the air intake filter of an air compressor?
18. If the intercooler pressure of an air compressor drops below normal, what is the probable trouble?
19. Dirt which causes compressor air valves to operate improperly can usually be traced to what three sources?
20. When inserting compressor air valves in a cylinder, what precaution must be taken?
21. What can be used as a seal against leakage at the threads of an air valve setscrew, if no lock nuts are provided for this purpose?
22. Why is a sponge or woolen yarn preferred over cotton as a filter in compressor control valves?
23. Why are air flasks, relay tanks, and separators of surface ships given a surface inspection every three months?
24. When starting a new compressor for the first time, what action should be taken?
25. How often must the diaphragm of a steam whistle be inspected and cleaned?
26. When installing a siren unit, what two factors should be considered?
27. How often should hardness and alkalinity tests be performed on boiler water?
28. If shore water has to be used in boilers, why must it first be evaporated in the ship's distilling plant?
29. Why should the salt-water piping in the drain cooler be frequently checked for leaks?
30. What type boilers are equipped with thermomechanical feed water regulators?
31. What type of boiler controls are generally used on fire tube boilers arranged for semiautomatic or automatic operation?

# CHAPTER 16

## NAVY REPAIR PROCEDURES

This chapter deals with the repair department organization of repair ships and tenders and procedures for handling repairs aboard ship and at repair activities. The fundamental difference between repair ships and tenders is one of function. Repair ships perform maintenance functions beyond the capabilities of a ship's own facilities. They are floating shops, with skilled workmen and many tools. Tenders, on the other hand, perform repair work, provide spare parts, and render other services to the ships they serve. Thus, on a repair ship there are general maintenance facilities for a number of types of craft, and stocks of commonly used repair parts. On a tender the facilities are specific to the type of ship tended, and the material items are peculiar not only to that type but also to the particular class composing the squadron to which the ship is attached. In addition, the squadron depends on the tender for ammunition, general stores, medical facilities, and often quarters, as well as for repair services.

Repair ships are classified as follows:

1. AR (Repair Ship)
2. ARB (Battle Damage Repair Ship)
3. ARG (Internal Combustion Engine Repair Ship)
4. ARH (Heavy Hull Repair Ship)
5. ARL (Landing Craft Repair Ship)
6. ARS (Salvage Vessels)

7. ARS(D) (Salvage Lifting Vessels)
8. ARS(T) (Salvage Craft Tenders)

Tenders are classified as follows:

1. AD (Destroyer Tender)
2. AS (Submarine Tender)
3. AGP (Motor Torpedo Boat Tender)

## REPAIR SHIPS (AR) AND TENDERS (AD)

In this training course, the discussion of repair ships and tenders is limited to the AR and the AD.

### Designation, Function, and Facilities

The modern AR is designed to meet the maintenance requirements for capital ships, such as battleships, cruisers, or carriers exclusive of the aircraft. Its shops consist of all components required for hull machinery, electrical, and ordnance work. They are the largest and most complete shops found on any repair ship or tender. The repair materials carried in stock are widely used in hull and machinery items, gyro parts, navigation and interior communications equipment, typewriter repair parts, electronic items, and motion picture equipment.

Some AR's were constructed for their present purpose; others were merchant marine hulls converted to naval use. Displacements vary from approximately 11,000 to 16,000 tons. The spaces aboard ship can accommodate from 35 to 65 officers and from 700 to 1000 men. Most AR's have two booms with a lifting capacity of 20 or 30 tons. The engineering plants develop from 2500 to 11,000 shaft horsepower, and generating capacity in both a-c and d-c varies from 1600 to 4500 kilowatts.

The modern destroyer tender, AD, is intended to meet the normal supporting requirements of 18 destroyers. The repair plant is planned to provide the equipment and capacity for the afloat repairs of the destroyers tended, of which the maximum number alongside at any one time is six. Some of these ships were originally designed as tenders, while

others are conversions from merchant marine types. The displacements range from 16,000 to 18,000 tons, and accommodations are provided for 50 to 70 officers and for 750 to 1200 men.

The tender is also equipped to furnish hospital and dental facilities to accommodate approximately 2 percent of the combined crews of the destroyers tended.

The engineering plant develops from 8500 to 12,000 shaft horsepower and the generator capacity, ranging from 2100 to 3500 kilowatts, is sufficient for the tender itself as well as for ships alongside. Compressed air, fresh water, and other services are also provided by destroyer tenders. These ships, as well as all other black-oil-burning repair types, are fitted for fueling at sea. Destroyer tenders carry approximately 1500 tons of oil usable for servicing other ships.

Materials carried include general and ship's stores, ammunition, torpedoes, and a 6 months' supply of repair items for the vessels tended. Main boom capacity is 20 or 30 tons, with additional smaller lifting services consisting of two 4-ton cranes and torpedo handling booms. To provide boating service for the ships tended, the tender is supplied with more than the usual number of small boats.

### Organization of Repair Ships and Tenders

The organization of a repair ship or tender follows the standard ship organization, with which you are already familiar. The organization of the Repair Department is similar in all types of repair ships and tenders. Some variations exist in the assignment of shop space to various divisions; for example, the foundry is sometimes located in the machinery division and sometimes in the hull division. The chart in figure 16–1 shows the organization of the repair department.

REPAIR OFFICER. On a repair ship or tender where service to other ships is a primary function, the repair officer is the officer detailed by CNO or the CO to head the repair department. The repair officer is primarily responsible for the maintenance of a well-organized and efficiently operated repair department. He is responsible for the maintenance

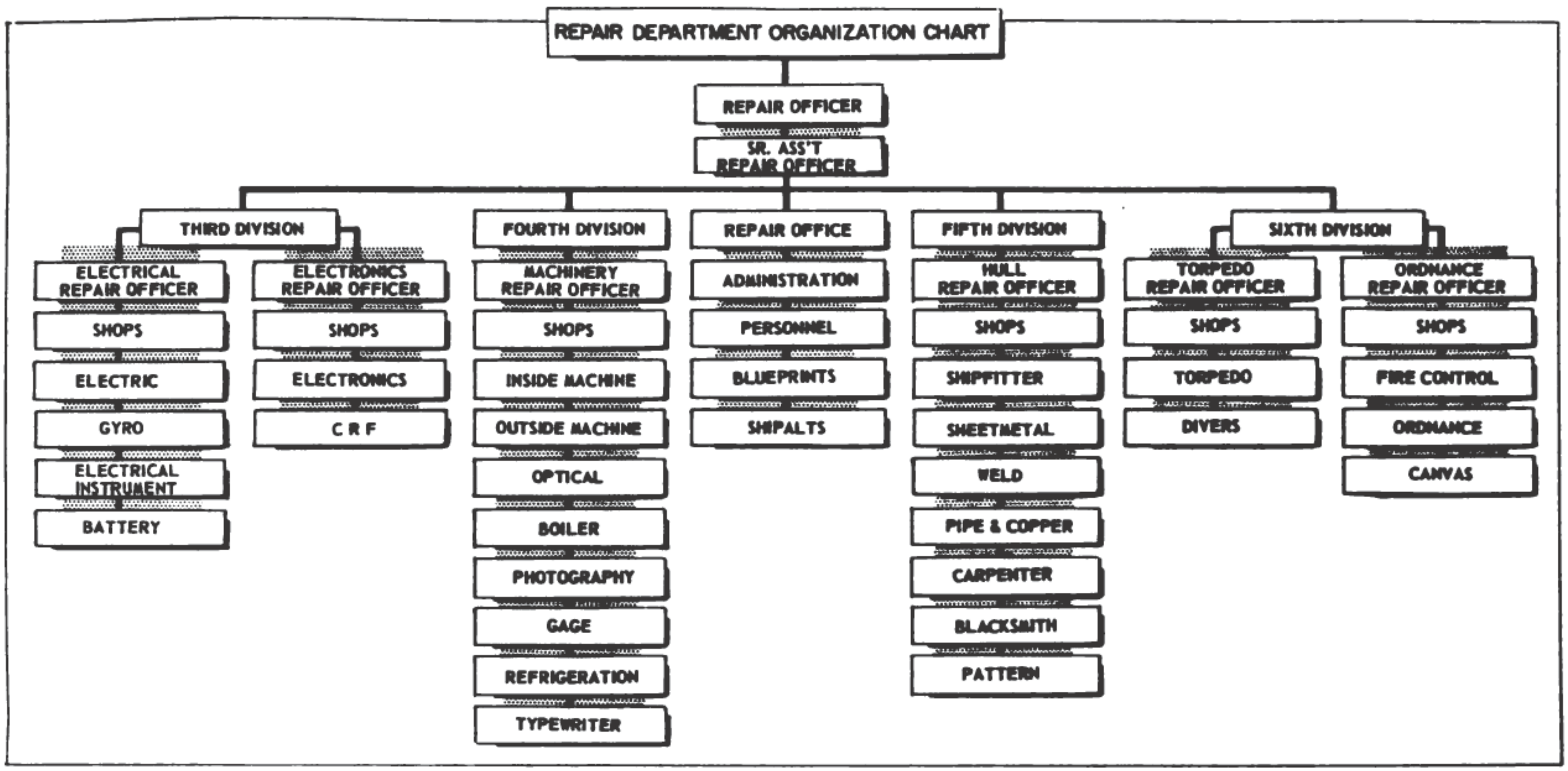



Figure 16–1.—Typical repair department organization chart.

and operation of the equipment assigned to the repair department. He is responsible for the training, direction, and coordination of personnel under his supervision. He must know the current work load of his department and must also keep the staff material officer (or the service division representative) informed of the current work status so that the latter can properly schedule and assign ships. In peacetime, when working under the allotment system, the repair officer is responsible for operating within the allotment granted, and for the initiation of requests for further funds if required.

The repair officer is responsible for the proper performance of the following specific functions:

1. Preparation of repair schedules.
2. Preparation of reports, forms, and orders pertaining to assigned functions and duties.
3. Supervision and inspection of repairs and services.
4. Review of work requests received from the ships assigned for repair.
5. Review of all personnel problems arising within his divisions in such matters as training, assignment, rating, and leave.
6. Cleanliness and maintenance of spaces assigned.

Assistant Repair Officer. In the absence of the repair officer, the assistant repair officer is primarily charged with the accomplishment of repairs on those ships made available by competent authority. He is usually responsible for the internal administration of the repair department, for department correspondence and dispatches, for the maintenance of adequate files and records and for the preparation of reports. His responsibilities also include the details of the training program for personnel in the repair department. the writing of job orders, and seeing that personnel receive important information, such as department orders.

In addition to general office administration, the assistant repair officer is often assigned the more specific job of keeping progress data on all outstanding work, supervising the photographic laboratory, supervising the drafting room, and

preparing requisition data for specific material. In performing this latter function he works closely with the supply department in order to expedite the preparation of requisitions and to initiate follow-ups on outstanding requisitions.

In addition to the assistant repair officer, the repair officer also has the following assistants: an electrical assistant, an electronics assistant, an engineering or machinery assistant, a construction or hull assistant, and an ordnance assistant.

DIVING AND SALVAGE OFFICER. The primary duty of the diving and salvage officer is the supervision of all diving operations. He is responsible for the maintenance and inspection of all diving equipment, and must see that it is available for use when needed. He must also see that diving instructions and precautions set forth in the *U. S. Navy Diving Manual*, 1948, are enforced.

The diving and salvage officer is also responsible for the adequacy and readiness of rigging equipment, and underwater tools such as burning, cutting, and welding outfits.

REPAIR DEPARTMENT DAY DUTY OFFICER. If the repair officer is absent, the day's duty repair officer will see that incoming ships are met by a boarding officer. He will also approve, execute, and expedite emergency and routine work.

## REPAIRS AND ALTERATIONS

Maintenance jobs may be divided into two major groups—repairs and alterations. Although repair ships and tenders are capable of handling both types of maintenance jobs, they are primarily concerned with repairs.

A REPAIR, as defined in *Navy Regulations*, is "work necessary to restore a ship or article to serviceable condition without change in design, materials, number, location, or relationship of the component parts." Repair work items are determined by the ship's force and approved for accomplishment by the ship's CO. If the work is such that it cannot be accomplished by the ship's force, but requires the service of an AR or AD, the items must be approved by the cognizant type commander.

AN ALTERATION is defined as "any change in the hull, machinery, equipment, or fittings which involves a change in design, materials, number, location, or relationship of the component parts of an assembly, regardless of whether it is undertaken separately from, or incidental to, or in conjunction with repairs." Requests for alterations originate from three sources: BuShips (other bureaus may originate requests for alterations to equipment under their jurisdiction, but this discussion is limited to alterations of BuShips concern, called SHIPALT's), the forces afloat, and CNO. In any case, BuShips administers the requests for alterations. If BuShips determines that the alteration is one affecting military characteristics (a NAVALT), it forwards the request to CNO for approval and action. If the alteration does not affect military characteristics, BuShips may approve and authorize it without reference to CNO. In general, alterations of the latter type are concerned with matters of safety, efficiency, economy of operation or maintenance, and the health and comfort of personnel.

## SHIPALT's

Each SHIPALT is identified by a composite number consisting of two serial numbers followed by the letter "A," "K," or "D." Serial numbers are assigned chronologically in the order in which alterations are approved. The first serial number is the TYPE SERIAL NUMBER; that is, the number of the alteration within a type (BB, CL, CA, etc.). The second serial number is the SHIP SERIAL NUMBER; that is, the number of the alteration for a specific ship within the type. The letter indicates the expenditure account chargeable.

For example, consider SHIPALT CVE 621A72—SIBONEY. CVE is the ship type designation (in this case an escort carrier); 621 indicates that the alteration is the 621st approved for CVE's; "A" designates the account to which the charges will be made; 72 indicates that this alteration is the 72nd approved for the USS *Siboney*.

## NAVALT's

NAVALT's, although basically SHIPALT's, concern items involving military characteristics, and as such they must be approved by CNO, who also establishes their priority for accomplishment. They are listed and handled in the same manner as SHIPALT's, but the use of the separate forms facilitates accounting and administration in BuShips.

### Alterations Equivalent to Repairs

According to *Navy Regulations*, an alteration is considered equivalent to a repair when it consists of:

1. The use of different materials which have been approved for like or similar use when such different materials are available from standard stock.
2. The replacement of worn-out or damaged parts requiring renewal by those of later and more efficient design previously approved by the bureau concerned.
3. The strengthening of parts which require repair or replacement in order to improve reliability of the parts and of the unit, provided no change in design is involved.
4. Minor modifications involving no significant changes in design or functioning of equipment but considered essential to prevent recurrence of unsatisfactory conditions.

Alterations equivalent to repairs may be approved and authorized by type commanders without reference to BuShips, provided they do not involve increases in weight or vertical moment. They are financed and otherwise administered in the same manner as repairs, except that their completion is reported to BuShips.

### Alterations and Improvement Program

The type commander maintains a master record of all outstanding SHIPALT's and alterations for the ships of his force. Sometimes this list of alterations is divided into 3 sections—SHIPALT's (including NAVALT's), ORDALT's (ordnance alterations), and alterations equivalent to repairs.

In order to maintain a master record of the alteration program, the type commander requires the ships to report the completion of any alterations, either by letter or by the pink copy (NavShips 99) of the completed SHIPALT, to BuShips, via the type commander. In addition, copies of the master list are sent to each ship quarterly. New alterations, when approved, are added to the list. Corrections, if any, are made and a corrected copy of the list is returned to the type commander.

In addition, BuShips maintains a record of the outstanding alterations for each ship. These alteration records must be accurate and kept up to date. When an alteration has been completed by all ships concerned, it is removed from the outstanding alterations list. Copies of this list (A and I program) are kept on file in the log room.

## REPAIR PROCEDURES AND AVAILABILITY

Ships are scheduled for routine overhaul periods alongside repair ships or tenders at certain intervals of time. These time intervals will vary according to the different types of ships. Destroyers usually undergo a tender overhaul period every 6 months. The time that a ship spends alongside a tender or repair ship is normally about 2 weeks. These overhaul periods are usually planned far in advance and depend upon the quarterly employment schedule of the ship concerned. During normal procedures the ship will know well in advance when it will go alongside a tender or repair ship for a routine overhaul period.

After a ship receives a tender assignment, listed in the employment schedule, the unfinished paperwork should be accomplished. An inspection is made to see that the current ship's maintenance project (CSMP) is up to date. Data from the appropriate CSMP cards are copied onto work requests, for repair ship accomplishment. (A description of how these CSMP cards are made up and maintained is given in chapter 18 of this training course.) When the CSMP card data are copied, the ship's serial number is also assigned

to work requests. Then the work requests are arranged in the order of their priority, for their respective groups, such as mechanical, electrical, and hull. In cases of tender and repair ship overhaul, alterations which are marked for accomplishment by forces afloat are included in the requested work items. In other words, the above approved alterations are included with the repair items and processed in the same manner.

The work requests, with the required number of copies, are sent with a forwarding letter to the type commander or to his representative, and are screened by the staff officer handling material and maintenance. Most of the ship's overhaul work list items are approved; some may be disapproved, some revised so that the work may be done by the ship's force; on some items, the ship may be required to furnish additional information. The amount of corrective action taken by the reviewing staff officer will depend upon how well the work requests are written and if they follow established policies. Upon the completion of this screening, the ship's approved work requests are forwarded to the repair ship or tender.

The ship must prepare the work requests in sufficient time so that all major work items will reach the repair ship or tender not less than 30 days in advance of the ship's arrival alongside. When supplementary work requests must be submitted, they should reach the repair activity before the arrival of the ship.

The procedures for handling repairs are essentially the same on tenders and repair ships. The method of accepting work requests, or the channels through which work requests flow to the repair department, may vary slightly. However, the preceding and following discussions will give you a good understanding of the usual normal requirements.

A vessel may not informally, and on her own initiative, enter a naval shipyard or come alongside a tender or repair ship for repairs. The control and disposition of a vessel is generally a function of the operating command. Thus, when outside repair assistance is needed, the vessel's type

commander—or in certain cases the task force commander—assigns the vessel an "availability" at a repair activity.

The term AVAILABILITY indicates that the vessel is available to a repair facility for repair, overhaul, and/or alteration. *Navy Regulations* defines availability as follows: "The period of time assigned a ship by competent authority for the uninterrupted accomplishment of work at a repair activity."

### Regular Overhaul

An availability for the accomplishment of general repairs and alterations at a naval shipyard or other shore-based repair activity is referred to as a REGULAR OVERHAUL. The period between regular overhauls for each type ship (generally 18 months) is recommended by BuShips and the type commanders. With the periods for the type established, each type commander with BuShips prepares a regular overhaul schedule for each vessel under his command, by projecting from the date of completion of the last regular overhaul. The type commander then requires his ships to submit their individual work requests, transfers funds to the appropriate naval shipyards, and directs the ships to report at the assigned date to the shipyards. This type of availability is of importance to the MM1 or C because his ship will be scheduled for regular overhauls and he will assist in making out work requests.

### Restricted Availability

When specific work is necessary a RESTRICTED AVAILABILITY will be requested. *Navy Regulations* defines restricted availability as follows: "An availability for the accomplishment of SPECIFIC ITEMS of work by a repair activity, with the ship present." For example, a restricted availability would be granted for the repair of a propeller blade of a ship. Many of the ships which come alongside a repair ship or tender will have been granted this type of availability.

### Technical Availability

An availability for the accomplishment of specific items of work by a repair activity, with the ship NOT present, is

known as a TECHNICAL AVAILABILITY. This type of availability is granted when a unit of auxiliary equipment, such as a pump, needs repairing—a unit which can be detached and left for repair while the ship continues on its mission. Since the ship will not be present during the availability, arrangements must be made for the ship to deliver the defective equipment and to call for it on completion of repairs, or to provide shipping instructions.

### Voyage Repairs

An availability for the accomplishment of emergency work which is necessary to enable a ship to continue on its mission and which can be performed without requiring a change in the ship's operating schedule or in the general steaming notice in effect is known as VOYAGE REPAIRS. This type of availability is very similar to restricted and technical availabilities except that a change in operating schedule is not involved.

### Upkeep Period

An upkeep period is that period of time assigned, by competent authority, for uninterrupted accomplishment of work by the ship's force or by other forces afloat. During this upkeep period the ship is anchored or in moorings.

### Arrival Repair Conference

As soon as a division or a unit arrives for an assigned availability, an arrival repair conference is usually held. Representatives of the ships of the repair department, and, usually, of the type commander are present at the conference. The conference serves to clarify all uncertainty for the repair department, which has received and studied the work requests in advance. The relative needs of the ships and the relative urgency of each job is settled.

### Services

The repair ship provides the primary services of steam and electricity in sufficient quantity to take care of heating and

lighting requirements and limited power for the ships alongside. (Fuel is not generally supplied except from service force barges.) In addition, the repair ship or tender usually takes over communications watches.

### Work Requests and Job Orders

The terms "work requests" and "job orders" are sometimes used interchangeably by personnel. This is not technically correct, because there is a difference in meaning of the two terms. Work requests are made up by the ship and forwarded through proper channels to a repair ship or naval shipyard. When the work request has been approved by the repair activity, it becomes a job order and a job order number is assigned. When this number is assigned, the work request becomes an actual job order to the repair personnel of a repair ship or tender. Naval shipyards, however, issue their own form of job orders when the work requests have been approved. In short, a job order is an approved work request.

### Getting the Repair Jobs Started

As soon as the work requests have been approved at the arrival conference, the jobs which require delivery of parts or material to the tender shops should be started immediately. Starting these repair jobs early is very important in getting all the necessary repair work completed. Some of the equipment, not needed for the operation of the ship, may be disassembled in advance so that defective parts can be delivered to the tender as soon as the work requests have been approved.

All material delivered to the tender should be properly tagged and identified. Metal tags, secured with wire, are preferred. The information on the tag should, if practicable, include the following: the number and name of the ship, the department and the division or space, and the job order number. The tender's assigned number should be used when possible. Reference material such as blueprints and manufacturers' instruction books should contain the ship's name and number.

### Ship-To-Shop Jobs

At times, repair jobs are designated by the ship, or approved by the repair activity, as "Ship-To-Shop" jobs. This indicates that the ship's force will do most of the repair work. For example, take a pump with a damaged shaft. Ship's force will disassemble the pump and remove the damaged shaft. The shaft is tagged, and brought to the repair activity machine shop. When necessary, the required blueprints are also delivered. The machine shop supervisor will check on the job and give an estimated completion date. When the shaft has been repaired or a new one made, ship's force will pick it up at the machine shop and return it to the ship. The new or repaired shaft is installed and the pump reassembled by ship's force. Inspections and tests are made to see that all conditions are satisfactory.

Repair jobs for such items as gages, valves, and portable equipment are always written up as ship-to-shop jobs.

In some cases repair jobs are written up for a repair activity to assist ship's force in accomplishing certain repairs. Many of these jobs can be called ship-to-shop jobs.

### Checking Progress of Tender Repair Jobs

The MM1 or C should check the progress of repair work for his space or equipment. Tender repairs which are being performed on board the ship that is being serviced can easily be checked by discussing the details of the job with the CPO in charge of the repair personnel.

Checking progress of work in the shops on the tender will require planning and coordination between your ship and the tender. The method used in checking progress should be one that does not necessarily interfere with personnel working in the shops.

Some tenders and repair ships have a CPO who acts as a ship superintendent. In general, his duties are as follows:

1. To act as liaison officer between the ships alongside and the tender in regard to repair department jobs
2. To act as a coordinator of shop work for the assigned ships

3. To report daily to representatives of the commanding officers of the ship alongside to ensure that the work is progressing satisfactorily

4. To maintain a daily progress report or chart which will indicate (a) the percent completion of each job; (b) the availability of plans, manufacturers' instruction books, or samples; and (c) the availability of material required for each job

5. To notify the ship to pick up completed material from the repair ship or tender shops

6. To notify ship's personnel to witness tests on machinery, compartments, and tanks occasioned by work performed

7. To obtain signatures from officers concerned in case of cancellation of a job order

8. To secure signatures from officers concerned on completion of job orders.

Where a tender or repair ship provides a ship's superintendent, the work progress on the tender can easily be checked, because your ship will be furnished with the necessary information by the ship's superintendent.

In cases where the services of a ship's superintendent are not provided by a tender or repair ship, it is advisable that the ship appoint a petty officer first or chief to perform similar duties for the division or engineering department.

The basic purposes for checking progress of repair work are to see that (1) jobs are not delayed, (2) no job is overlooked or forgotten, and (3) all jobs undertaken are satisfactorily completed at the end of the repair period.

## PROCESSING WORK REQUESTS

During World War II a work request was simply a list of items with the information necessary to define each job. Often, in extreme emergencies, the work request was set out in the form of a dispatch. In peacetime, work requests are made on printed forms provided for that purpose. Ship's personnel fill in the necessary data and sufficient copies of

**WORK REQUEST**
DATE:

| REPAIR | BUREAU | TITLE | Group or Index No. | Ship's Serial No. |
|---|---|---|---|---|
| Eng.(Mech.) | Ships | ---- | S46 | 20-53 |

| | | |
|---|---|---|
| USS DOOR CV3333 | Classification ------- | Priority Routine |

| COMAIRLANT | Priority | Ship's Force | Repair Ship | Shipyard |
|---|---|---|---|---|
| Approval | Routine | | X | |

Date Listed 4/23/53 Started Completed

Repair Ship or Shipyard (cross out one) USS SPEED AR10 J.O. No.

Brief of Repair: Include any necessary data, comment on material, and list blueprints where essential. Use back of this form if necessary.

LEAVE BLANK

IDENTIFY: Main condensate pump, Worthington Pump and Machinery Corp., Harrison, N.J. Serial No. 1120239; model A78; size 4 1/2"; speed 1145.
LOCATION: Forward engine room.
REPAIR: Remove, manufacture, and replace second-stage impeller locking sleeve. This sleeve also acts as a wearing surface for packing. It is worn to such an extent that the packing has to be renewed weekly.
SPARES: No spare sleeve provided with pump.
PLANS: Mfg. draw. No. SL-6174; BuShips plan No. CV3333-S4601-245092.
SHIP'S FORCE WILL ASSIST: Dismantle and deliver shaft assembly to machine shop; pick up and assemble pump when repairs are completed.
SHIP'S INSPECTORS: LT T.J. Ward; J.J. Johnson, MMC; M.E. March, MR1.

John Doe
Commanding

Figure 16–2.—Sample work request.

the work requests are submitted for distribution to all interested personnel. Figure 16–2 illustrates a common type of work request form used by a type command.

Work request forms are filled out by ship's personnel with sufficient copies for distribution as follows: original and one copy for the repair ship (some repair ships require two copies), one copy for return, after approval by the type commander's representative, to the originating ship, and one copy for the type commander's maintenance files. The entries made on the form shown in figure 16–2 may be described briefly as follows:

Bureau: The title of the bureau having cognizance over the item to be repaired is filled in here.

297637—55——34

Title: This space is no longer applicable.

Group or Index Number: Each group of machinery, structure, or equipment aboard ship bears a file number such as S16, access openings; S35, laundry; S41, main propelling machinery; and S51, boilers.

Ship's serial number: Each ship numbers its work requests serially throughout a calendar year.

The ship's serial number is usually made up of a composite number—for example DD785–EM25–53. This number is made up of 3 parts. The first part is the number of the ship, which indicates that it is a work request from the DD785. In the second part, E indicates that it is a work request from the engineering department; M indicates that it is a mechanical job, and the number "25" is the individual serial number of the mechanical job or work request. The third part indicates the year in which the request is made. In other words, it is the 25th engineering mechanical work request from the engineering department in the year 1953, from the DD785.

USS: The name of the ship is entered here.

Classification: Some items of equipment bear a security classification which is indicated here.

Priority: This is the priority requested by the ship—urgent, routine, or deferred.

Ship's force, repair ship, shipyard: Check the activity which will accomplish the indicated repair.

Date: This line is self-explanatory.

J. O. number: Job order number is filled in by the repair activity.

Brief of repair: A specific statement of the work desired is necessary; it is often desirable to include the symptoms of faulty operation. It is further desirable to list the applicable drawings and to indicate whether or not they can be furnished. Where applicable, a statement is made as to which part of the work will be accomplished by the ship's force (for example, dismantling, reassembly, and delivery to and from the repair shop). Such instructions as "do work as necessary," "check," or "open up, examine, and repair" are

almost meaningless, and are not acceptable. It is common practice to include the name of the ship's officer or the CPO who should be contacted for details if necessary and who will be responsible for inspection of the completed job.

Approval: The type commander's maintenance officer, or his representative, fills in the title of the type command in this space. The CO of the ship usually reviews and signs all requests.

Priority: This is the priority assigned to the job by the screening authority.

Leave Blank: In this space the repair activity enters such data as (1) number of man-hours on the job, (2) stub requisition numbers of material drawn, and (3) signature of the person signing for the completed job.

## SHIP'S FORCE MAINTENANCE AND REPAIRS

Each ship should, in so far as practicable, be self-sustaining with regard to normal repairs. Each ship should be well supplied with material, tools, and repair parts and equipment in order that a great deal of its repair work can be accomplished. Training and repairs should be undertaken under the supervision of the most competent and experienced personnel. In cases where personnel are not familiar with the manner of making specific repairs and tests, they should be instructed to take advantage of shipyard or repair ship availabilities or tender assignments, to observe how such work is undertaken. Budget limitations in peacetime, and military operations in wartime, require that, as far as possible, a ship be self-sufficient.

### Administration of Maintenance Work

The CSMP, the Machinery History, the inspection methods including work inspection and progress inspection during overhaul, and other methodical procedures, when properly used, guarantee systematic inspection of material, provide adequate records of inspection and work, and virtually assure that all material is given proper care and attention.

These and other material administrative measures have the added effect of promoting thoroughness and a sense of responsibility in naval personnel. The technical excellence and reliability which the Navy has is due, in large measure, to systematic material administration carried on in conjunction with carefully planned and analyzed operating procedures.

### Preventive Maintenance

The purpose of preventive maintenance is to maintain satisfactory material conditions and ensure that the equipment or machinery is always ready for service. A regular schedule of cleaning, inspections, operations, and tests is required to ensure trouble-free operation and the detection of incipient faults before they become a major source of difficulty.

CHECK-OFF LISTS. Ships are required to establish and maintain, for each station, check-off lists which will indicate periodic tests and inspections for each item of machinery or equipment at that station. The purpose of these check-off lists is to guard against any phase of the ship's force maintenance work being overlooked.

ROUTINE INSPECTIONS AND TESTS. The majority of routine inspections and tests are generally performed by the ship's force. Most of the inspections and tests are quite simple in nature; others require planning so that they can be undertaken during upkeep or overhaul periods. Shipyard and repair ship assistance is not to be requested unless the test or inspection is actually beyond the capacity of ship's force.

## SHORE-BASED REPAIR ACTIVITIES

Shore-based repair activities include naval repair activities under the management control of BuShips or CNO, and commercial ship repair yards under contract to the Navy.

### Organization of a Shore-Based Repair Activity

Although all shore-based activities have a similar organization, it is not a standardized one, and details will depend upon the size of, and the repair facilities and local conditions

at, the repair base. Some shore-based repair activities have more or less an abbreviated form of naval shipyard organization; others adapted their organizations directly from that used aboard a repair ship or tender. The major difference between the two organizations lies in the existence or nonexistence of separate planning and production departments. The larger the shore-based repair activity, the more it tends to conform with a naval shipyard type of organization.

### Procedure for Obtaining Repairs

The work requests proceed from originating ship to the type commander's representative, who authorizes an availability, in accordance with operational commitments. The requests will then go to the local service force representative, such as the service squadron or division commander, for assignment. Finally, the requests go to the repair facility.

From time to time, between maneuvers, your ship will be anchored in places where shore-based repair facilities are available. With the approval of the type commander, who furnishes the funds for repairs, emergency and voyage repairs may be accomplished, depending upon the time available. When practicable, it is a wise policy to get urgent repairs accomplished by shore-based repair activities.

## NAVAL SHIPYARDS

A naval shipyard is a component activity of a naval base. The primary mission of the naval shipyard is to render service to the fleet in the form of efficient and economical building, repairs, alterations, overhauling, docking, converting, or outfitting of ships and related special manufacturing, and necessary replenishment of stores and supplies where required.

Naval shipyards are designated as home yards and as planning yards. A home yard is a shipyard to which a particular vessel is usually assigned by CNO for accomplishment of repairs and alterations. A planning yard is a shipyard which has been designated by BuShips as the yard which

undertakes the design work for the type ship allocated to it by BuShips. Naval shipyards perform many other functions, such as manufacturing, research, and design. These functions will not be considered in this training course.

### Administration of Repairs

CNO has delegated his authority to the fleet commanders to grant availabilities at naval shipyards for regular overhauls, voyage repairs, emergency repairs, and technical and restricted availabilities. The fleet commanders have further delegated to the type commanders this authority for voyage repairs and technical availabilities, and in some cases restricted availabilities. To describe the type commander's part in dealing with availabilities, only the regular overhaul will be discussed. It should be noted that, in general, repair work cannot be accomplished by any repair activity unless it is granted funds with which to do the job. Repair activities do not have money in their own right for this purpose. The MBS (Maintenance Bureau of Ships) repair allotment administered by the type commander is utilized to reimburse shore repair activities for labor charges and material costs, and to reimburse tenders for material costs incurred incident to repair to hull, machinery, and equipment under the cognizance of BuShips. Funds for improvements to vessels (SHIPALTS) are administered by BuShips for all material under the cognizance of that Bureau.

### Procedure for Submitting Repair Lists

The rules for submitting shipyard work requests prior to a regular overhaul are laid down in general in *Navy Regulations*, and in detail in fleet and type commander regulations. The following procedure is followed in the Atlantic Fleet. Commanding officers are required to submit their naval shipyard work lists to the type commander 60 days prior to a scheduled regular overhaul. The type commander will carefully inspect these lists. The various items are approved, disapproved, changed, or corrected in accordance with stand-

ard repair policies. The lists are then forwarded to the naval shipyard not less than 30 days prior to the start of the overhaul.

Ships having mimeograph machines are required to submit 30 copies of the work lists; others, an original and 6 copies. A separate (departmental) work list is made out for each of the following headings: hull, engineering (mechanical), engineering (electrical), electronics, and ordnance.

Items of work are listed in the relative order of priority for each work list of the groups listed above. After these work lists have been completed, a ship's priority index is made up. The priority index is usually made up at a conference of all heads of departments and the executive officer. The various items are selected from the individual repair lists and assigned in an over-all order of priority for the ship. The ship's priority index usually consists of two columns of numbers; the first column is the order of priority, and the second column is the repair item number. A sample of this list is shown below:

| *Priority* | INTEGRATED PRIORITY LIST | *Work Item No.* |
|---|---|---|
| 1 | | EM–1 |
| 2 | | EM–2 |
| 3 | | O–1 |
| 4 | | H–1 |
| 5 | | EE–1 |
| 6 | | E–1 |
| 7 | | H–2 |
| etc | | etc. |

NOTE: H=Hull.
EM=Engineering (Mechanical).
EE=Engineering (Electrical).
E=Electronics.
O=Ordnance.

Certain procedures are usually followed in making out a departmental work request list. Some type commanders require that each work item should be submitted in the following form and contain the designated information:

1. Description of the item, including location, name plate data, and where applicable, plan numbers.

2. Report of existing defects in the item to be repaired.

3. Complete and full description of repairs required to place the item in satisfactory operating condition. The repair parts, which are required to effect repairs, should be clearly indicated.

4. Reference should be made to authorizing correspondence, where applicable. If none is applicable or exists, report "none."

5. Specify whether "ship-to-shop" or any other assistance is to be provided by ship's force.

6. Ship's inspecting officer or petty officer. The person(s) specified should have detailed information on the repair item.

The following repair request item is given as a sample:

EM–12 (S55)

(a) Fuel Oil Heaters No. 1 & 2, location B–1–1 and B–3–1. BuShips plan No. DD692–S5503–12 Alt. 3.

(b) BuShips *Manual* requires that fuel oil heaters be tested every five (5) years.

(c) Test steam side of fuel oil heaters to hydrostatic pressure of 1½ times designed operating pressure (900 psi). Test oil side to hydrostatic pressure of 1½ times designated operating pressure.

(d) BuShips *Manual*, Article 55–103 (2) & (4).

(e) Ship's force will assist by preparing system for test.

(f) Ship inspector: Lt. Jones
Johnson, BTC

To ensure that all repair items are written up properly and none are overlooked, it is imperative that the CSMP be kept up to date at all times.

In the Pacific Fleet, the procedure for submitting routine naval shipyard repair requests is somewhat different in detail. Each item of work is submitted on a separate work request form, with sufficient copies. The sheaf of work requests is accompanied by a priority list.

## Procedure for Accomplishing Alterations

The list of authorized alterations that are to be accomplished at a routine naval shipyard overhaul is prepared by BuShips. Approximately 90 days in advance of the ship's arrival, BuShips will forward to the shipyard, type commander, and the ship a list of approved alterations in the priority applicable to the individual vessel. Funds, based on shipyard estimates, are provided by BuShips.

Prior to the above procedure, BuShips usually provides the type commander with a prospective priority list of alterations to be accomplished on the ship due for a routine overhaul. The type commander may submit, to BuShips, recommended changes in SHIPALT priority list. The type commander usually requests recommendations from the ship concerned in regard to the SHIPALTS that should be completed during the shipyard overhaul period.

SHIPALTS marked "ship's force" of "forces afloat" are, as a rule, not undertaken by the naval shipyards.

## Naval Shipyard Arrival Conference

When the ship arrives in the shipyard for a routine overhaul, an arrival conference is held. This conference is supervised by the planning officer and attended by representatives from the ship, type commander, naval shipyard planning department, and other interested parties. The ship's repair request list (which has been studied) and individual item costs estimated by the shipyard Planning Department are reviewed. When necessary, the details of the repair items are discussed and the work to be done is decided upon.

The limitations of the funds available, by the type commander, determine to a great extent the amount of repairs that will be accomplished during a naval shipyard overhaul period. The estimated cost of each repair job, when approved at the conference, is added up to give the total cost. When the total cost approximately reaches the amount of funds appropriated, the shipyard will not accept any more repair requests. Under this condition, in case there are

several additional important jobs that should be accomplished, the type commander must furnish more funds to cover these jobs.

### Naval Shipyard Organization

Included in the naval shipyard organization under the control of the shipyard commander are the Planning, Production, Public Works, Supply, Comptroller, Medical, Dental, Administrative, Management Planning and Review, and Industrial Relations Departments. (See fig. 16-3.) The Ordnance Officer, the Electronics Officer, and the Aeronautics Officer are specialist members of the staff of the shipyard commander in charge of their respective offices, with status comparable to that of Heads of Departments. These specialist officers also perform duties as deputies of the Planning Officer and the Production Officer.

Figure 16-3 shows a basic administrative chart of a naval shipyard. In considering engineering repairs, the shipyard departments of most interest to ship's personnel are the Planning and the Production Departments.

The Planning Department, in accordance with its title, does all the planning in regard to the submitted work requests. A certain number of civilian planners, each one a specialist in his field, is assigned for the ship. After a certain amount of inspection and research has been completed, job orders are written up for each approved work request. These job orders include such items as instructions and procedures, reference plans, information on material and repair parts, shops that are to do the work, and the estimated man-hours and cost. The planning officer, or his assistant, must approve each work request before it is authorized and a job order made out and processed.

The Production Department includes the various shops and repair facilities of the naval shipyard. The actual work is done by the Production Department. The production officer is responsible for seeing that all work issued for accomplishment by the Production Department is accomplished within the time allowed and funds allocated, and in accord-

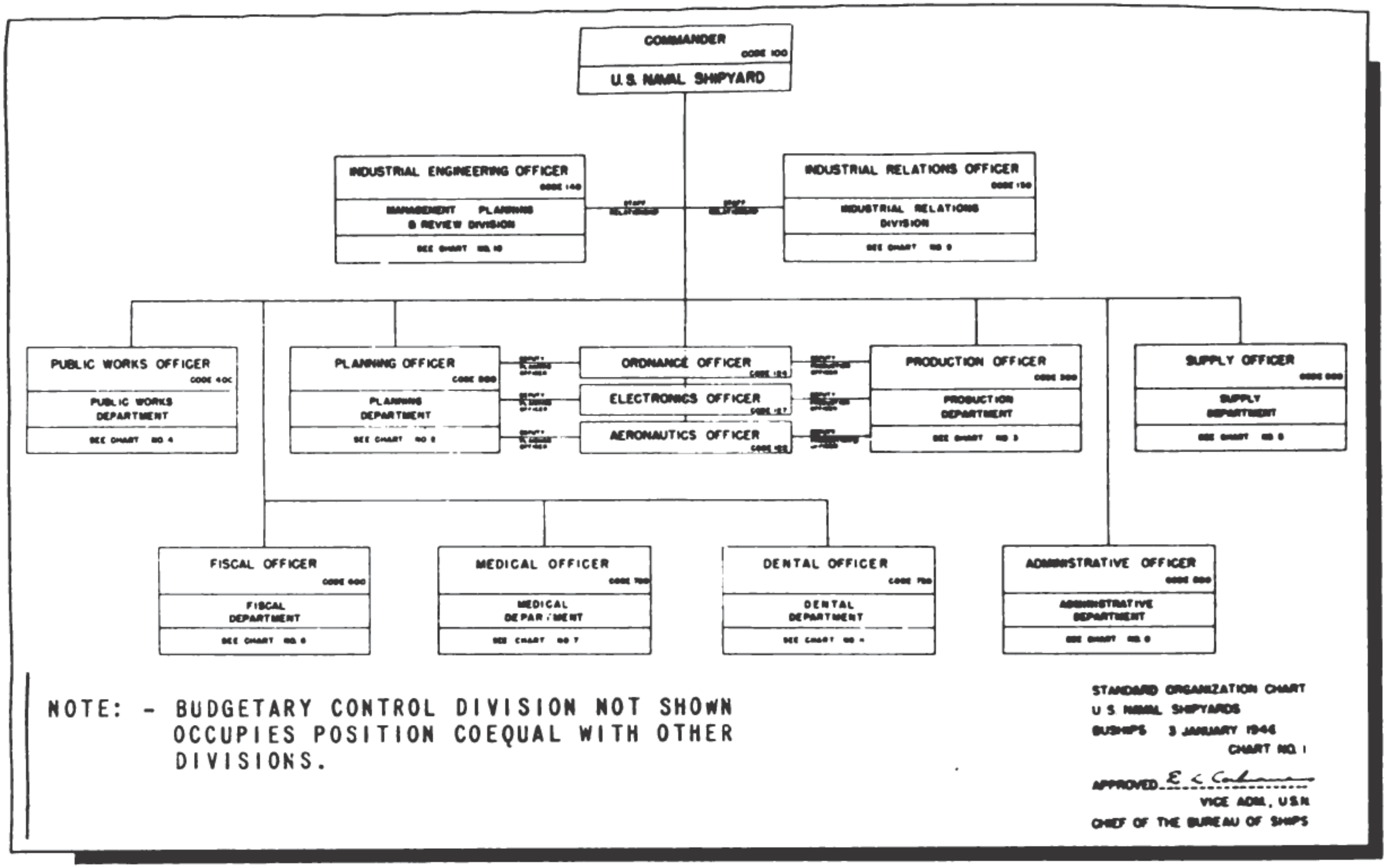



Figure 16-3.—Naval shipyard organization chart.

ance with applicable instructions and sound engineering practice. The Production Department will not accomplish any work unless it is authorized to do so, in the form of a job order, by the Planning Department, or as directed by the shipyard commander.

## Naval Shipyard Shops

A shop in a naval shipyard is a separate unit assigned certain specific work, usually by trades, and manned by qualified men adept in the type of work assigned. A list of the various shops is shown in the following table:

| *Shop No.* | *Shop Name* |
|---|---|
| 01 | Supply Shop. |
| 02 | Transportation Shop. |
| 03 | Power Plant. |
| 06 | Central Tool Shop. |
| 07 | Public Works Shop. |
| 11 | Shipfitter Shop. |
| 17 | Sheetmetal Shop. |
| 23 | Forge Shop. |
| 25 | Gas Manufacturing Plant. |
| 26 | Welding Shop. |
| 27 | Galvanizing Plant. |
| 31 | Inside Machine Shop. |
| 33 | Director Shop. |
| 35 | Optical Shop. |
| 36 | Ordnance Shop. |
| 37 | Electrical Manufacturing Shop. |
| 38 | Outside Machine Shop. |
| 41 | Boiler Shop. |
| 51 | Electric Shop. |
| 56 | Pipe and Copper Shop. |
| 61 | Shipwright Shop. |
| 63 | Joiner Shop. |
| 64 | Woodworking Shop. |
| 67 | Electronics Shop. |
| 68 | Boat Shop. |
| 71 | Paint Shop. |
| 72 | Riggers and Laborers Shop. |
| 74 | Sail Loft. |
| 81 | Foundry. |
| 93 | Print Shop. |

| *Shop No.* | *Shop Name* |
|---|---|
| 94 | **Pattern Shop.** |
| 96 | **Paint Manufacturing Shop.** |
| 97 | **Ropewalk.** |
| 99 | **Temporary Service Shop.** |

All productive shops in the yard are under the supervision of the shop superintendent. Each shop is under the control of a civilian, usually a master mechanic. The ratings of civilian supervisors in the shops and similar activities are as follows:

Master.
Foreman.
Chief Quarterman.
Quarterman.
Special Leadingman.
Leadingman.
Snapper.

It is to your advantage to know the title of the various naval shipyard personnel that you come in contact with on the various repair jobs.

## Ship's Superintendent

The ship's superintendent is a naval officer, attached to the Production Department of the naval shipyard, and acting as a liaison officer between the ship and the yard. In most yards it is customary to assign one officer as ship's superintendent for each ship; however, conditions may vary according to the size of the ship and the number of ships present.

The ship's superintendent is usually on hand at the dock when the ship arrives and ties up. He checks to make certain that the required dock services are promptly furnished. He attends the arrival conference and has a list of the ship's work items. He has, as a rule, a good knowledge of the repair work that is to be accomplished on the ship during the overhaul period.

The Ship's Superintendent maintains a close relationship

with the ship's officers and key personnel, civilian planners assigned to the ship, shop supervisors, supervisors in charge of repair details on board ship, and other naval shipyard supervisory personnel. When any delays or interferences develop on a repair job he can immediately check with the responsible yard personnel and obtain detailed information, or assist in overcoming any difficulties that may be present. The Ship's Superintendent can usually furnish or obtain any information on a job that is requested by ship's force. He also can keep the ship's key personnel posted on the progress of all repair jobs. The Ship's Superintendent is available for advice on (1) repair procedures, (2) unsatisfactory work by yard personnel, and (3) tests made by the shipyard. The primary duty of the Ship's Superintendent is to assist the ship's personnel in all matters regarding repair when the ship is in the yard.

### Ship's Progressman

The Ship's Progressman is a civilian, who is assigned to the Production Department of the naval shipyard, and who maintains a running check on the progress of all naval shipyard work being done on the ship. It is customary to assign one progressman to each ship but the number of ship's superintendents will vary in accordance with existing conditions.

In addition to keeping the Production Department informed, the Ship's Progressman will keep the ship posted on the progress of each job. A good Ship's Progressman, especially for a small ship, will perform most of the duties assigned to the ship's superintendent. Because of his experience and knowledge of the naval shipyard, the Ship's Progressman is in a good position to give assistance, advice, and information in regard to any repair problems that may develop.

### Checking on Progress of Work

During a routine naval shipyard overhaul period the ship has to submit weekly shipyard progress reports in accordance with the type commander's instructions. In order to submit

weekly progress reports, as well as for their own information, ship's supervisory personnel must keep an accurate check on the progress of work at all times. This should include ship's force work as well as naval shipyard work. One of the best methods of keeping track of the numerous repair jobs is by means of a progress chart. This progress chart, which can be obtained from the Naval District Printing and Publications Office, is filled out and posted. Any number of copies can be used as necessary. Usually one is made out for naval shipyard repair work, one for alterations, and another one for ship's force work. The job order number and title are listed in the left-hand columns. The right-hand columns are usually marked to show the percentage of completion for each job listed. One copy of the progress chart is usually posted outside the log room, and kept up to date by assigned ship's key personnel. Many ships use the same progress chart for tender or repair ship overhaul periods.

Some naval shipyards hold a weekly repair progress conference. This conference is attended by ship's representatives as well as by all interested shipyard activities. Usually jobs that are encountering delays or other difficulties are discussed. Valuable knowledge and information regarding the progress of naval shipyard work can be obtained by attending these conferences.

In checking on the progress of a job one should have the detailed information of what repair work is to be accomplished. This information can be obtained from the job orders that are issued by the Planning Department of the yard. The ship receives 3 or more copies of these job orders, which are usually delivered by the Ship's Progressman. In most cases a complete set of these job orders is kept on clipboards, or file folders, in the log room.

A copy of the job orders that are applicable to your division is usually kept by your division officer. It is important that you understand the details of these job orders before you start checking on the progress of the individual repair jobs.

## Obtaining Additional Repair Jobs

It may be necessary to prepare supplementary repair lists to include items arising subsequent to the submitting of the original lists. Additional repairs are sometimes required because of recent voyage casualties, or because of conditions discovered during shipyard tests and inspections. In submitting the supplementary list, the same procedure must be followed as for the original list, and the supplements are dovetailed into the ship's priority index.

In the period (approximately 3 months) between the submission of the original work lists and the ship's arrival at the shipyard there might be some unforeseen difficulties arising which will require shipyard repairs. In cases of this kind, an added repair list is made out which is called the 1st supplement. If possible, this should be done prior to the ship's arrival at the yard.

The naval shipyard conducts numerous tests and inspections in accordance with an established policy for ship's request items. These tests and inspections may bring out some unknown repair items. Usually when these initial tests and inspections have been completed a supplementary repair list is made out to cover such defects as have been found. This repair list is called the 1st or 2nd supplement, as the case may be.

## Inspection Duties of Ship's Force

The inspection of work being done by a repair activity for a ship is the responsibility of both the repair activity and the ship. The repair activity should require such inspections to be made as will ensure the proper execution of the work and adherence to prescribed specifications and methods. Ship's personnel should make such inspections as may be necessary to determine if the work is satisfactory, both during its progress and when completed. The responsible CPO should schedule his work in such a manner that he will have time to inspect and check the progress of naval shipyard work going on in his space, or being performed on equipment for

which he has the responsibility of maintenance and upkeep. A check should be made to see if required tests are made by the shipyard before the job is considered fully completed. The naval shipyard job order will list any tests that have to be made by yard personnel.

In case any unsatisfactory work is being performed by shipyard personnel you should follow the instructions put out by your engineer officer. Talking it over in a friendly manner with the workmen will usually solve your problem; otherwise, you should notify your division officer or engineer officer, who can take up problems of unsatisfactory work with the ship's superintendent. In exceptional cases the CO of your ship can take necessary action in accordance with *Navy Regulations.*

On many ships it is customary for your division officer or engineer officer to check with you before he signs a job order as being completed. By a continuous inspection of shipyard work, and checking off the jobs that have been satisfactorily completed, you can furnish the required information without unnecessary delays.

### Drydocking the Ship

The ship is drydocked each time it goes to the naval shipyard for a routine overhaul. The routine procedure is to keep the ship in drydock for as short a period as practicable. As soon as the necessary work has been completed the ship is removed from drydock.

Before the ship enters drydock you should check the Machinery History and the CSMP to make sure that you have the detailed information on the sea valves for which you are responsible. It is a good idea to make up a check-off list from the ship's blueprint of sea valves in order that no valve will be overlooked. In other words, you want to be fully prepared to inspect the fireroom sea valves because this work should be started as soon as the ship is drydocked.

A ship entering drydock should be without list and without excessive trim. Trim in excess of one foot per 100 feet of length normally makes the docking operations hazardous. If practicable, the trim should be brought below this

limit before an attempt is made to dock the ship. No weight, fuel oil, or water should be shifted, added, or removed while the ship is in drydock, unless specifically authorized by the docking officer. Any tanks containing water or oil should be either full or empty, if practicable. When permission to shift weight is given, the responsibility for keeping an accurate record of the amount and location of the change of weights rests with the ship's personnel. Provisions should be made to ensure that the ship will lift from the blocks without taking a list when the drydock is flooded.

When the ship is in drydock, no fuel oil or other inflammable liquid should be drained or pumped into the dock.

When ships are docked in cold or freezing weather, the valves, pipes, or similar fittings attached to the shell should be examined and any water remaining therein should be drained to prevent freezing and possible cracking of the fitting.

Whenever a ship is drydocked all sea valves must be examined. The result of the examination must be entered in the engineering log. This examination should include the condition of the yoke, yoke rods, valve stem, and securing bolts, as well as the condition of the internal parts of the valve. At least two of the bolts holding outboard valves to sea stools should be removed from each valve which is to be inspected; the remaining bolts should be sounded with a hammer. If defects are found in a bolt, all the bolts for that valve should be removed for inspection. Where all bolts have been removed, the gasket should be replaced. All necessary repairs to place sea valves in good condition should be made while the ship is in drydock. Openings in the hull caused by ship's force disassembling sea valves should be closed temporarily, at the close of working hours, by replacing the valve bonnets, or by blank-flanging the openings. The docking activity is responsible for openings on which it is making repairs. At the end of working hours, a report should be made to the engineer officer in regard to the status of all sea valves. The same information should be entered in the engineering log.

Before the drydock is flooded, all sea valves must be carefully inspected to ensure that they are properly secured. The result of this inspection should be reported to the engineer officer and entered in the engineering log.

While the drydock is being flooded, there must be a continuous inspection of sea valves until the ship is afloat and all valves are under a normal working head of water. Any unsatisfactory conditions must be reported at once to the engineer officer so that the docking officer can be notified. A report of leakage must be made in sufficient time so that the docking officer can stop flooding, if necessary, before the ship lifts from the supporting blocks.

### Dock Trial

A dock trial is held whenever major repairs have been made by a naval shipyard on propulsion machinery. The trial is usually held as a precautionary procedure at the completion of a routine naval shipyard overhaul period.

To prevent delays or interference with the testing of the main engines and associated equipment, all auxiliary machinery should be tested at least one day prior to the dock trial.

The ship's engineering personnel, under the direction of the engineer officer, should make such tests of boilers and machinery, with the ship properly secured to the dock, as will enable them to ascertain their condition and readiness for operation at sea. Sufficient inspections and tests should be made to ensure that the machinery and equipment have been properly repaired and are in good operating condition. Any defect, deficiency, or maladjustment will have to be corrected either by ship's force or the shipyard. When necessary, the dock trial should be repeated until conditions are satisfactory.

## SUMMARY

The basic difference between repair ships and tenders is one of function. Repair ships are primarily concerned with maintenance, in support of various types of vessels; tenders,

on the other hand, support in all respects the specific types of ships to which they are assigned.

When a vessel requires outside repair assistance, the vessel's type commander—or task force commander in some cases—assigns the vessel an availability at a repair activity. An availability indicates that the ship is available at a repair activity for repair, overhaul, and/or alteration.

Ships, like machines and equipment, can operate only a certain length of time without repairs. To keep them in prime condition, definite intervals of time must be allotted for their overhaul and repair. In spite of regular maintenance procedures, accidents and derangements will occur, necessitating emergency repair work. Repairs within the capabilities of the ship's force are accomplished by the ship's force. However, when repairs cannot be accomplished by the ship's force, aid must be obtained from a repair activity afloat or ashore.

Material upkeep should be given constant attention. Defects and deficiencies within the capacity of the ship's force to correct should be repaired as soon as possible after discovery. Repairs beyond the capacity of the ship's force to accomplish, and ship's force items that cannot be undertaken immediately, should be recorded in the CSMP, for early accomplishment.

Whenever it becomes necessary to repair shipboard machinery at a naval shipyard, the MM1 or C will be responsible for the preparation of job orders and data pertaining to work which is to be accomplished. During a naval shipyard overhaul, the MM1 or C is responsible for the necessary inspections to determine if the work is satisfactory, while in progress and when completed. In turn he furnishes the engineer or division officer with detailed information of the work being performed by the naval shipyard. In addition, the MM1 or C is responsible for seeing that the shipboard equipment or machinery to be repaired is properly disassembled and delivered to the repair activity, picked up, and returned to the ship after the work has been completed. The petty officer concerned is also responsible for approving, re-

installing, and testing the machinery and/or equipment after it has been repaired.

## QUIZ

1. What is the fundamental difference between a repair and a tender, with respect to the kind of support which each vessel gives to the ships assigned?
2. Which modern repair ship is designed to meet the maintenance requirements for capital ships?
3. What is the primary responsibility of a repair officer aboard a repair ship or tender?
4. Who is generally responsible for handling the internal administration of the repair department?
5. Who is responsible for the adequacy and readiness of underwater tools and associated rigging equipment?
6. Requests for alterations concerning propulsion machinery originate from what three sources?
7. What kind of alterations require the approval of CNO?
8. What information is supplied by the two serial numbers following the word "SHIPALT"?
9. When worn-out or damaged parts are replaced by approved parts of later design, what type of maintenance work is involved?
10. Where are copies of the alteration list found aboard ship?
11. A ship scheduled for routine overhaul will normally be alongside a tender or repair ship for how long a period?
12. When is an availability at a repair activity assigned to a vessel?
13. What type of availability would be granted for accomplishment of specific items of repair work by a repair activity, with the ship present?
14. A technical availability is granted under what conditions?
15. When does a work request become a job order?
16. If a repair job has been designated by the ship or approved by the repair activity, as "Ship-To-Shop" job, who will do most of the repair work?
17. What are the basic reasons for checking progress of a repair job in a tender shop?
18. Who fills out work requests?
19. What is the purpose of preventive maintenance?
20. What is the purpose of periodic check-off lists aboard ship?
21. Who authorizes funds for the repair of ships at a shore-based repair activity?
22. What is a home yard?
23. How many days prior to a scheduled regular overhaul, at a naval shipyard, must commanding officers submit their naval shipyard work lists to the type commander?

24. In order that all repair items are written up properly and none are overlooked by ship's personnel, what record should be kept up to date at all times?
25. Who prepares the list of authorized alterations that are to be accomplished at a routine naval shipyard overhaul?
26. Which SHIPALTS are generally not undertaken by naval shipyards?
27. Who supervises a naval shipyard arrival conference?
28. At a naval shipyard, who is responsible for approving each work request before it is authorized and processed?
29. The ship's superintendent at a naval shipyard is available for advice on what issues?
30. In general, who delivers copies of naval shipyard job orders to the ship?
31. Under normal conditions, when is a ship drydocked?
32. What should be done before a ship enters the drydock?
33. What will the inspection of sea valves include when a ship is drydocked?
34. When is a dock trial required to be held at a naval shipyard?

# CHAPTER 17

## ENGINEERING MATERIALS AND SUPPLIES

Materials and supplies are of vital importance to the successful operation of the engineering department. Adequate quantities of general repair materials and repair parts for items of engineering spaces equipment are the responsibility of both the engineering department and the supply department. The duties of the supply officer are to procure, receive, stow, issue, and account for all types of stores involved in the support of the ship; however, engineering department personnel must take the initiative to keep abreast or ahead of usage. Repair experience, advance planning, and careful use of stocks are all necessary elements in avoiding costly and embarrassing delays in completing a job.

The supply officer keeps his stock in various supply department storerooms from which the material may be drawn. The engineering department also has storerooms for issuing items which are drawn in small quantities—i. e., the ship has both wholesale and retail storerooms. Material in the engineering department storerooms is charged against the department allotment when it is originally drawn from the supply department storerooms or a supply activity ashore.

### CLASSES OF MATERIAL

In general, there are three classes of material: General Stores Material, BuShips Controlled Material, and BuShips repair parts.

## General Stores Material

General Stores Material (GSM) is that material listed in the General Stores Section of the *Catalog of Navy Material*. In general, BuSandA has complete inventory control over standard stock items. However, BuShips, by mutual agreement with BuSandA, exercises through BuSandA certain temporary controls over procurement, distribution, and/or issue of items for the exclusive use of BuShips, where such arrangements will better serve the forces afloat and BuShips. General stores materials are usually the consumable supplies carried in stock for maintenance and operating purposes; they generally do not include nonconsumable equipment or repair parts for this equipment.

## Classification and Cataloging

In order to systematize the large range of materials used aboard ship, stocks are arbitrarily divided into classes. Designations have been made for 99 classes, of which the following are examples: class 17, electrical equipment; class 33, gaskets, packing hose and fittings, rubber, and plastics; class 39, lumber; class 43, bolts, nuts, rivets, screws, and washers; class 60, steam propulsion apparatus, heat transfer equipment, and nonelectric power transmission equipment. Each item has a stock number, the first two numbers being the class number. All general stores items are listed in the General Stores Section of the *Catalog of Navy Material*, published by BuSandA. Other stock items are listed in various sections of the *Catalog of Navy Material*, or in various repair parts lists, stock lists, etc., published by the Bureaus or by the Supply Demand Control Points which maintain inventory control over various categories of material used by the Navy.

In the near future, invoices and boxes will be received under a new stock numbering system, consisting of a 4-digit Federal class and a 7-digit number; for example, 1234–567–8910. Your supply officer will have been informed of the

significance of this change, and can tell you how it will eventually affect the supply system afloat.

### BuShips Controlled Material

Machinery or equipment intended primarily for shipboard use is under the control of BuShips and is referred to as BuShips Controlled Material. In general, BuShips Controlled Material consists of items of permanent (nonconsumable) shipboard equipment (in most cases shown on ship's general arrangement drawings or working plans) requiring installation arrangements such as special power leads, piping connections, or foundations. Under normal circumstances, such material is not removed from storage without direct permission of BuShips.

Because of the nature of BuShips Controlled Material, it is difficult, in a brief discussion, to draw a sharp line of demarcation between an item in this class of material and repair parts for such an item. There are bound to be borderline cases. In order to clarify these cases, the *BuShips Material Directory and Requisitioning Guide*, NavShips 250–550, lists such repair parts: items such as turbine blading, propulsion reciprocating engine crankshafts, turbine rotors, etc. (Complete sets of repair parts for items of BuShips Controlled Material are classified as BuShips Controlled Material when in store.)

### BuShips Repair Parts

The third class of material is BuShips repair parts. These are items such as parts, fittings, or accessories of equipment which is BuShips Special Material. In order to control these parts properly, BuShips and BuSandA have established supply demand control points (SDCP), to check the inventory control of BuShips Repair Parts. BuShips repair parts are under the inventory control of the Ships Parts Control Center, Mechanicsburg, Pa.; the Submarine Supply Office, Philadelphia, Pa.; and the Electronics Supply Office, Great Lakes, Ill. Each SDCP has its own distribution system, consisting

of primary, secondary, and reserve stock points. These distribution points carry the repair parts required for the support of the fleet units.

BuShips repair parts are generally defined as those parts and assemblies which are wearable, expendable, and replaceable during normal repair. The BuShips allowance list indicates the repair parts (except electronics) authorized and required to be on board.

### Repair Parts

On board, repair parts are essential replacement items carried by every ship, as specified in the ship's allowance lists. Repair parts are frequently used by the ship's force and by the repair ship in repair work for the ship carrying them. However, tenders carry tender stocks of repair parts for the type ships tended. Some repair parts are stocked ashore only since industrial assistance may be required to install them. Others are not carried in stock, because there is little likelihood that they will be needed, or because they can be fabricated by forces afloat, tenders, or shipyards.

CUSTODY OF EQUIPMENT. On large ships the supply officer has custody of all on-board repair parts in drawer and shelf stowage (Supply Department Storerooms) and should have custody of all machinery repair parts boxes. In this case the supply department will have control of machinery repair parts. Where suitable space for the consolidated stowage of repair parts boxes is not available for assignment to the supply officer, the various department heads will be required to assume the custody of repair parts boxes until a bin-drawer stowage system is installed.

For the assignment of custody and maintenance of repair parts boxes on small ships, two different methods are commonly used. In one case, a leading petty officer has the custody and maintenance of all repair parts for the engineering department. He is assisted by a man from each division or gang. The other method commonly used is to assign the custody and maintenance of repair parts to the CPO or the

leading petty officer in charge of machinery for which repair parts are provided.

Equipage is a term applied to certain categories of portable and semiportable materials which are necessary to a ship if it is to properly carry out its mission. Equipage is further divided into items requiring custodial signature and items for which it is necessary only to keep a stock record.

The engineering department is responsible for signing equipage custody records for the following material:

1. BuShips material (including special tools) that is designated as "Expenditure Account, Series 12,000." (Series 12,000 was formerly designated Title B.)

2. Boxed sets of repair parts and independent repair parts designated "Expenditure Account, Series 12,000."

The supply department maintains an equipage stock card and custody record (SandA Form 306) for accountable items of material. Every receipt and expenditure of this equipage by the engineering department is recorded on the stock card. When the engineering department has been given actual custody of equipage, a duplicate card form, the Equipage Custody Record (SandA Form 306a) is provided. These cards are generally signed by petty officers to whom the custody is delegated. These actual custodians of the equipage are usually furnished with carbon copies of each custody record they have signed. Where applicable, temporary transfers of equipage and custody to individual men in the engineering spaces are acknowledged by a signed receipt.

All equipage should be inventoried once a year. The inventory should be completed within the third quarter of the fiscal year, and within 30 days after the date it is started. For the purpose of annual equipage inventory, repair parts should be inventoried only by sets and independent repair parts. (Expenditure Account, Series 12,000.)

Any shortages found to exist during the course of an inventory check should be covered by requests for survey, listing any facts available as to the cause of the loss. Items found to be unserviceable should not be reported as "on

hand" but should be repaired or covered by requests for survey.

An officer relieving another as head of the engineering department should have an inventory made of all equipage in the custody of his department. The relieving department head should then sign the original supply department equipage stock cards, thus acknowledging the receipt of the equipage concerned. Within 20 days after taking charge, the incoming officer should complete the inventory.

Petty officers who are custodians of equipage should hold an inventory with their individual reliefs when they are being relieved or transferred. The relieving petty officer, upon completing a satisfactory inventory, should sign the custody cards concerned.

Inventory of Repair Parts. At the beginning of a fiscal year, the head of each department having custody of machinery repair parts will submit to the CO a schedule for the inventory of repair parts. This schedule should indicate the dates during which the particular allowance group or subgroup inventory will be made. At least once during the fiscal year, a practical and realistic schedule should be provided for the inventory of each machinery repair part item. On 30 June of each year, each department head will submit a memorandum to the CO, stating that the inventory has been completed. In case the inventory has not been completed, an explanation, along with the date of probable completion, must be submitted.

The annual inventory of repair parts must be planned in advance and an orderly schedule followed. Requisitions must be made out for any deficiencies found during the inventory check. A record of the inventory, and the name of the person making it, is maintained.

Control and Issue. When the department head has custody of repair parts he is responsible for the control and issuance of these numerous items. As soon as a repair part is issued or used, the custodian should make out a stub requisition for a replacement. The original and a duplicate of a Request for Repair Parts (SandA Form 302) should be at-

tached to this stub requisition. This form, along with the stub requisition, will be submitted to the supply officer for the preparation of a replacement requisition, and for retention with the stub requisition, and will be used to charge the ship's (or department's) allotment upon the receipt of the replaced part. The duplicate of the SandA Form 302 should be kept with the set of repair parts to which it pertains or else filed as directed by the engineer officer.

Approval of the engineer officer is necessary before any repair parts under his custody may be transferred to another ship. The engineer officer should consult the supply officer and the CO on questions concerning the transferring of repair parts. This procedure does not apply to supply ships or tenders.

When installed machinery is to be removed from the ship, all repair parts pertaining to that machinery should also be removed from the ship. In cases where repair parts of the removed machinery can be used on board ship, special instructions are generally issued regarding their retention and disposition.

Machine parts which are worn out or damaged in use need not be surveyed when replaced by individual repair parts. Surveys of major repair parts should be made when these parts have been damaged or lost before being issued. A copy of the survey form, or a notation as to the survey made, should be included with the replacement requisition.

PROCUREMENT. On large ships, where the supply officer has custody of boxed repair parts, procurement action for replacement will be initiated upon receipt of the stub requisition (SandA Form 307) from the repair parts storeroom keeper.

Aboard a small ship, repair parts are under the custody of the engineer officer; supply action is initiated upon receipt of a stub requisition signed by the engineer officer. If necessary, a Request for Repair Parts (SandA Form 302) should be completed with all the essential data. This data may be obtained from the Machinery Index. However, the name of the repair part, or piece number, the unit of quan-

tity, and similar information can be obtained from the allowance list, from the repair parts box packing list, or from the manufacturer's instruction book.

The requisition should also include the allowance list group, page, and line number for each repair part requested. The effective date of the allowance list page (found in the lower left corner) should also be indicated on the requisition.

Requisitions should also show the current standard Navy stock number as reflected in the Master Cross Reference Listings, Allowance Lists, Repair Parts Lists, or any other available source of standard Navy stock numbers. If no standard Navy stock number is available, all name-plate data and similar information which would enable interpretation into a standard Navy stock number should be listed. These requests must bear realistic deadline delivery dates and priority assignment (including justification), and they are to be submitted via channels as prescribed by the cognizant Fleet Command.

RECEIPT AND INSPECTION. When repair parts to be kept under the custody of the engineering department are received aboard ship, they should be issued directly on receipt. When these repair parts are issued to the ship, a representative of the engineering department (usually a designated petty officer, or a storeroom keeper) will receive the material and sign the receipt invoice. The signed invoice is forwarded to the supply officer by the storekeeper of the supply department, who is in charge of receiving stores aboard ship. The engineering department representative who receives the material should carefully check the repair parts against the invoice, to ensure that the material is that requested, and that the number of items is correct. In addition, he should check the material for any damage which might have occurred during shipment.

If repair parts are kept in the custody of the supply department, inspection of those parts on receipt may be performed by the repair parts storekeeper. If the storekeeper is not technically qualified to perform this inspection, tech-

nical personnel from the department concerned should be assigned to assist in the identification and inspection of the repair parts in question. If repair parts received on board ship are wrapped in a protective coating, this coating should not be disturbed unless there is inaccurate or insufficient information on the label of the wrapper. A new repair part should be labeled or tagged, if necessary, and placed in its proper bin or box. The repair parts records should be kept up to date.

On board ships where repair parts are under the custody of the engineering department, the inspection and identification of repair parts must be performed by engineering personnel, usually a leading petty officer.

When material is received aboard ship, it usually is identified with a Standard Navy Supply Number (SNSN). Engineering department personnel should list this stock number opposite the item on the allowance list; this will save time and trouble in future ordering.

STOWAGE. Whenever possible, repair parts should be stowed in special storerooms, giving consideration to security and ease of handling. On small ships where it is impracticable to stow repair parts boxes in storerooms, the boxes are generally located in the same space as, or near, the machinery to which they pertain. In this case the repair parts boxes are placed in specially made brackets, usually on bulkheads.

Where the supply department has custody of repair parts, special storerooms are now provided on board ship. These new type storerooms have a large number of bins and drawers for individual stowage of repair part items. Bin stowage is the most recent technique in the stowage of Navy technical repair parts. Inasmuch as this type of stowage has a considerable number of advantages over repair part box stowage, most tenders and large vessels are being converted from repair part boxes to bins. The savings in space and weight realized through the elimination of the repair parts boxes and of the duplication of repair parts have proved so effective that eventually all vessels will be converted to

bin stowage. It is interesting to note that the new DL class destroyers have bin and drawer stowage for repair parts.

The department having custody of the repair parts boxes, or individual repair parts, is responsible for ensuring maximum protection of the parts. Repair parts boxes should be properly secured in brackets or bins. The contents of each box should be protected against undue motion. On units such as complete pump rotors the wearing rings, or other loose items, should be properly secured to prevent motion, with resultant wear or damage to the parts.

It may become necessary to relocate repair parts boxes that are located in unfavorable places. Inspections should be made to see that boxes are not located in damp or wet places, in places where it is excessively hot, or in places where there is a possibility of damage to the box and its contents.

If practicable, repair parts packed in wooden boxes should be removed and placed in bins, or the wooden box should be replaced by a metal box. Where necessary, a work request can be made out for the manufacture of a sheet metal box.

On small ships where repair parts boxes are located throughout the ship, it is customary to place padlocks on all boxes to prevent the contents from being disturbed by unauthorized personnel. One set of keys is kept by the custodian of the repair parts boxes; another set of keys is kept in the log room. All keys have identification tags attached to them.

Records of Locations. On small ships where repair parts boxes and individual repair parts are under the custody of the engineering departments, the repair parts boxes are found throughout the ship. Therefore it is necessary to use a master locator system so that a specific repair part, or repair part box, can be located without unnecessary delay. Different systems may be used, but a complete, accurate, and up-to-date record must be maintained. The MM1 or C should know how to locate repair parts on his ship.

Procedures commonly used to locate repair parts and repair parts boxes on board ship are as follows:

1. Repair parts boxes are identified by stamped or sten-

ciled data, giving the number of the box and the name of machine or equipment for which the parts are supplied. The identifying number is a composite one, containing the letter "S" and two sets of numbers. For example, if a box is numbered S47–16, the number 47, in accordance with the Navy material filing system, will indicate that the box contains repair parts for a pump. The number 16 will indicate that it is the 16th box of repair parts for pumps. The letters or name on the box will indicate the type of pump. Care should be taken to see that your men do not remove or paint over the identification data on a repair parts box.

2. When a new ship is placed in commission, the building yard usually furnishes the ship with a master stowage list of all repair parts boxes. This stowage list has several columns—box number, title (name of parent machine or unit), size of box, weight of box, and location of box (compartment, athwartship location, and frame number). An indication as to whether the parts are electrical, mechanical, or both, may be made under the title column. This master stowage list of repair parts boxes must be kept up to date.

3. Each repair parts box is provided with a packing list, usually attached to the inside of the box cover. This list itemizes all repair parts in the box; in addition, it usually carries the tag numbers, so that each item can be readily identified.

4. Ships, when placed in commission, are usually provided with a master list of the repair parts which are stowed in each box. This master list is made up of a duplicate copy of the packing list for each repair parts box on board ship. The box numbers appear on the list in numerical order. The location of the particular box is entered on the top of the front page of each individual copy of the packing list. When a repair parts box is moved from one location to another, all records must be promptly corrected to show the new location.

5. The manufacturer's instruction book for a piece of equipment carries a list of repair parts, usually in the back



297637—55——36

of the book. The identification numbers and the names are given for each part listed.

6. BuShips allowance lists contain a list of repair parts, special tools, and accessories for each unit of machinery and equipment.

7. The individual repair parts in a box usually have tags attached, or are labeled on the outside of the wrapping paper. This method of tagging provides a simple means of identification and is especially useful when inventory checks must be made. This method of identification should be followed when new replacement parts are placed in the box.

8. Repair parts are sometimes furnished without boxes. Identification tags should be attached to small items placed in the engineer's storeroom. Identification numbers should be stenciled on large items, such as turbine lifting gear. Shipping tags may also be attached to such items.

9. To aid in keeping repair parts boxes in their proper place, the box number is generally stenciled on the box receiving bracket or on the bulkhead behind the box.

10. In cases where leading petty officers have custody of repair parts for their division or space, appropriate duplicate box stowage and packing lists are usually provided. These leading petty officers should see that the lists are kept up to date and that any corrections made are entered on the master lists.

## Storerooms

The importance of correct stowage should not be underestimated. Storerooms should be arranged and maintained to permit maximum stowage capacity, access to all stores, preservation and orderly arrangement of stores, and security and safety of stores.

Maintaining good order is largely a personal matter. You should take pride in keeping a storeroom neat, clean, and in good condition. This applies particularly to small parts where orderliness is essential because you must be able to find, when needed, a large number of small items—packing, gaskets, studs, washers, nuts, bolts, screws, etc.

In supervising an engineering storeroom, consideration should be given to the following factors:

1. Stowage of material should be neat and orderly.
2. Bins and shelves should be numbered.
3. Material should be identified by means of label cards for each bin, or by means of shipping tags attached to the material.
4. In addition to the name, size, and other information, the label card should contain the stock number for reordering purposes.
5. Stock tally cards should be maintained for all items in the storerooms.
6. Material should be properly identified when placed in the storeroom.
7. Material should be preserved against rust and corrosion.
8. Care must be taken, with many items, to provide proper stowage in order to prevent damage of items.
9. Bins and shelves should have bars, plates, or other means of keeping material in the bins, in order that the storeroom can be properly secured for sea.
10. In accordance with requirements, a careful selection should be made of the type and amount of material to be kept in the storeroom.
11. It is necessary to have a good system of stocking and reordering material, in order to have material on hand at all times.
12. Care should be taken to see that accountable items such as gages and thermometers are properly issued, and that replacements are promptly obtained.
13. Defective, worn-out, or obsolete items should not be kept in the storeroom. When necessary, such items should be surveyed and replaced with new ones.
14. A CPO or MM1, assigned to supervise a storeroom, should instruct the personnel on proper storeroom operation and maintenance procedures. Inspections should be made to see that everything is in order.

15. A CPO should see that personnel in a storeroom render satisfactory services and cooperate with personnel from other engineering spaces.

### BuShips Allowance List

BuShips furnishes each ship with a set of allowance lists. The allowance list is the official source which contains the allowance of machinery, equipment, and material for a ship. A detailed description of the Allowance Lists will not be given in this chapter. Therefore, personnel concerned should carefully study their ship's allowance list, if they are not already familiar with it.

The Ship's Allowance List is divided into "S" groups, based on the Navy filing system, in the same way that BuShips *Manual* is divided into chapters. (For example, group S41 would refer to propulsion machinery and group S47 would be for pumps.) On the top of each page the major unit of machinery or equipment is listed. This is followed by the major component parts of the unit, and an itemized list of accessories (if any), special tools, and repair parts. Shore-based repair parts are also listed for some of the major units of machinery or equipment.

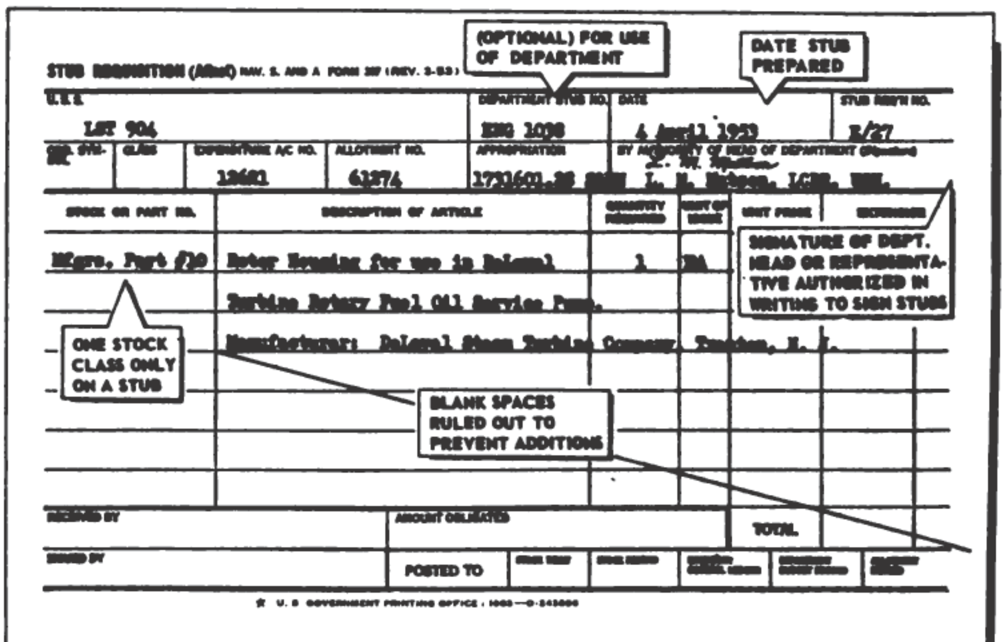
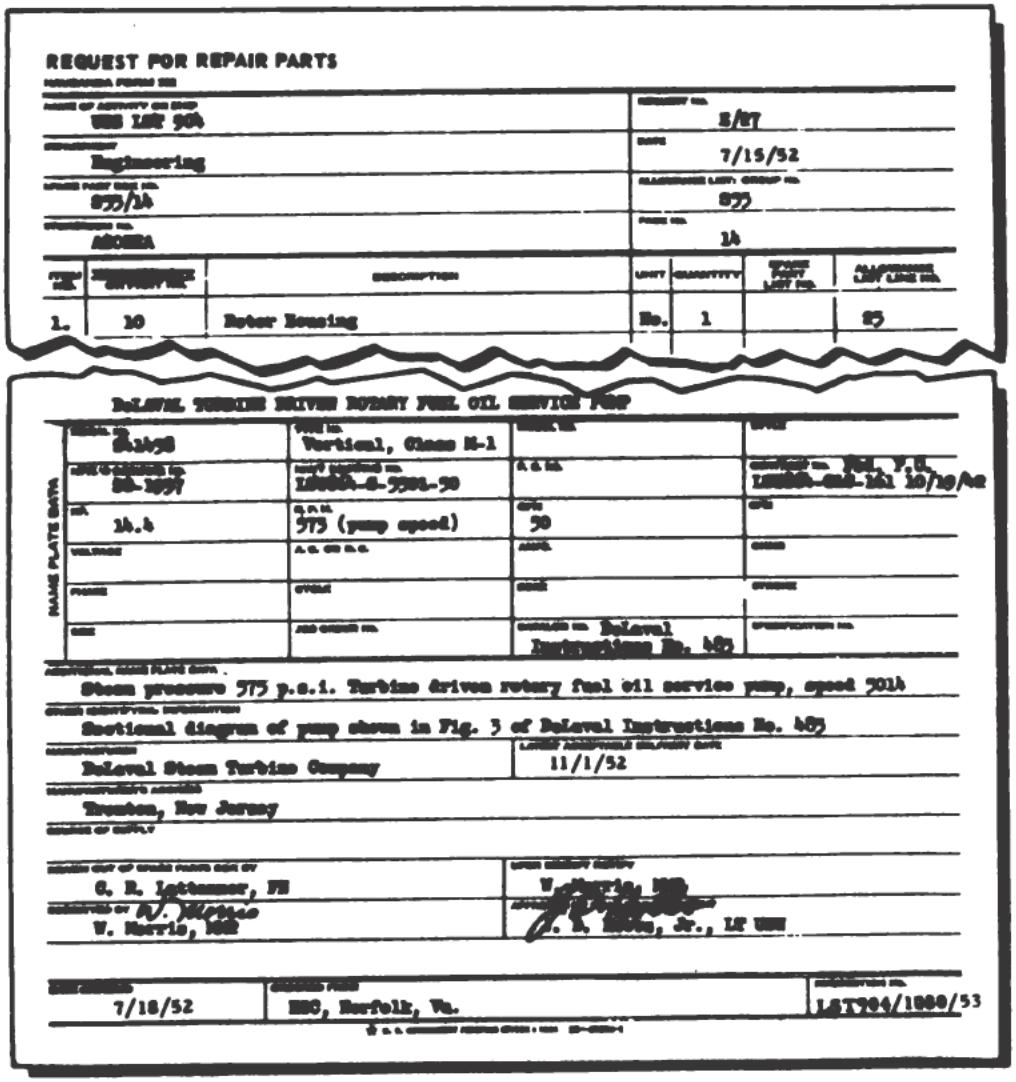



Figure 17–1.—Sample stub requisition.

When the material classification and the identification of the required repair parts is known, the next step is the process of requisitioning such parts. Figures 17–1, 17–2, and 17–3 show the principal forms used in the process.

The stub requisition, or Form 307, is used for any type of material—GSM items such as packing, gaskets, bolts, or hand tools, as well as for repair parts. Each division has its own book of stubs which is used as required for necessary supplies. The division officer initials the requisition and the engineer officer is the authorizing officer.

If the item required is a repair part which is not standard


REQUEST FOR REPAIR PARTS

Engineering

7/15/52

14

1. | 10 | Rotor Housing | No. | 1 | 85

Vertical, Class H-1

14.4

575 (pump speed)

DeLaval Instructions No. 485

Steam pressure 575 p.s.i. Turbine driven rotary fuel oil service pump, speed 5014

Sectional diagram of pump shown in Fig. 3 of DeLaval Instructions No. 485

DeLaval Steam Turbine Company

11/1/52

Trenton, New Jersey

7/18/52

NSC, Norfolk, Va.

LST904/1080/53

Figure 17–2.—Sample requisition for repair parts.

REQUISITION AND INVOICE
NAV. S. AND A. FORM 49
REVISED JULY 1949

LST904/1080/53
REQ. NO.

INV. NO.

| | |
|---|---|
| TO: SUPPLY OFFICER. SSD, NSC, Norfolk, Va. | U. S. S. (50904) LST 904 |
| THE FOLLOWING ARTICLES, WHICH ARE NOT IN EXCESS, ARE REQUIRED. DELIVER TO Supply Officer, USS LST 904 | DATE 7/18/52 — BUREAU Ships |
| | APPROPRIATION CHARGEABLE 1731601.28 S&FN Allot 61274 |
| BY Priority C 1 November 1952 | EXPENDITURE ACCOUNT 12621 |
| PACKAGES TO BE MARKED Reqn. LST904/1080/53 RP Box S-3/11 | DATE OF SHIPMENT — BILL OF LADING NO. |
| | SHIPPED VIA |

REMARKS
DDD assigned to meet operating schedule of this vessel

R. T. Ford
R. T. FORD, ENS
(SUPPLY OFFICER, OR COMMANDING OFFICER, OR STORES OFFICER) U. S. N.

| ITEM NO. | STANDARD STOCK CATALOG NO. OR CLASS NO. | DESCRIPTION OF ARTICLE | UNIT OF QUANTITY | QUANTITY REQUIRED | QUANTITY FURNISHED | UNIT PRICE | EXTENSION |
|---|---|---|---|---|---|---|---|
| | Mfgrs. Part No. | | | | | | |
| 1. | 10 | ROTOR HOUSING | No. | 1 | | | |
| | | For use in: DeLaval Turbine Driven Rotary Fuel Oil Service Pump Manufactured by: DeLaval Steam Turbine Company Trenton, New Jersey. | | | | | |
| | | Pump Data: Serial No. 241458; Mfgr Dwg No. SG-1937; B.H.P. 14.4; Type No. Vertical, Class M-1; Navy Dwg No. LST864-S-5501-50 | | R.P.M. 573; G.P.M. 50; Steam Pressure 575 psi; Turbine Speed 5014 normal; Contract No. LST864-GA-4161 Dated 10/19/42 | | | |
| | | Sectional diagram of pump shown in Fig. 3 of DeLaval Instructions No. 483. | | | | | |
| | | As shown in Machinery Allowance List Part I, Group S55, Page 14 Line 25 | | | | | |
| | | No other requisitions for this item outstanding. | | | | | |

Important: Vessel shall include only items in one stock class on this form.

TOTAL

| CHECKED BY | PACKED BY | POSTED AND PRICED | | RECEIVED THE ABOVE MENTIONED ARTICLES |
|---|---|---|---|---|
| RECHECKED | EXTENDED | VERIFIED | 1 | DATE |
| ISSUED BY | | | | BY U. S. N. |

**Figure 17–3.—Sample requisition and invoice.**

stock, the identifying data must be shown on NavSandA Form 302 (fig. 17–2). The supply officer must be furnished accurate and complete information concerning the desired part.

The supply officer prepares and sends out the requisition form (fig. 17–3). If there is insufficient time for routine handling of an emergency requisition, a dispatch is sent to a supply activity.

The REQUISITION PRIORITY classifications currently used are as follows:

Priority A: Emergency; this classification is used when a vessel in the forward area is inoperative or immobile because of the lack of the part requested.

Priority B: Overhaul; this classification is used for a request for repair parts for vessels undergoing or immediately scheduled for overhaul.

Priority C: Ship allowances; this classification is used to fill shortages or make replenishments of parts stocked. Priority C is assigned automatically when no priority is specified.

### BuShips Material Directory and Requisitioning Guide

General instructions governing all supply activities initiating requests for BuShips material are found in *BuShips Material Directory and Requisitioning Guide*, NavShips 250–550. This publication defines the class and cognizance of material used by BuShips and outlines the proper requisitioning procedure for each part. In addition, BuSandA *Manual* and the type commander's instructions contain specific, detailed information on the procedure for submitting requests.

Except in emergencies, BuShips Controlled Material may be purchased only by the Bureau or with the specific approval of BuShips.

### Not In-Excess Requisitions

Responsibility for the statement on any ship's requisition that material is not in-excess of allowance rests with the CO of the requisitioning ship.

NavSandA Form 43, or the Not In-Excess Requisition, is used when ordering the following:

1. Equipage on a ship's allowance list not in greater quantity than necessary to bring the amount on hand and on order up to full allowance (expenditure account in the 12000 series).

2. Consumable material listed in the *Catalog of Navy Material* or ship allowance lists, or items which for the requiring ships are comparable in end use to any items so listed (expenditure account in the 13000 series).

3. Material required for immediate expenditure for repairs or alterations, or to replace materials so expended.

### In-Excess Requisitions

An In-Excess Requisition (NavSandA Form 44) must be used for any item of equipage which is not listed in the requisitioning ship's allowance list. This requisition form must also be used in ordering material that is on the requisitioning ship's allowance list, if the material is being ordered in such quantity as to place on board an amount in excess of that authorized by the ship's allowance list.

The requisitioning ship is responsible for obtaining all necessary approval regarding its own "in-excess" requisitions.

## SURVEYS

One of the administrative duties of a CPO or MM1 will be to see that all material for which he is responsible is in good condition and on board ship. If the condition of any accountable material or equipment is unsatisfactory, immediate steps should be taken to initiate appropriate action to survey and replace the material. Since he may be required to make out a rough copy of the survey request form, he should become familiar with the survey procedure.

The survey procedure usually consists of the following steps:

1. Request for survey
2. Action by the CO on the request for survey
3. Preparation of the Survey Report
4. Action by the reviewing officer (normally the CO) on the survey report
5. Expenditure of material from the records on which carried, when recommended by the survey report and approved by the reviewing officer

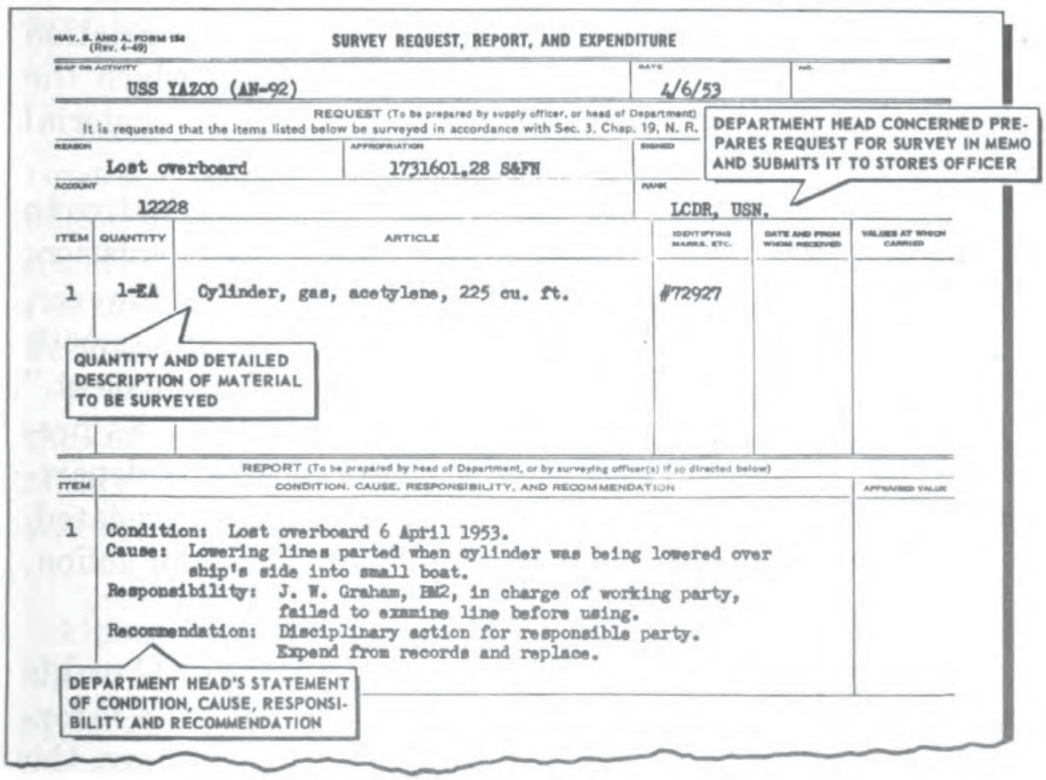
Each of the preceding steps will be discussed in the following paragraphs. The survey routing procedure as set forth in the following discussion is to be considered as a guide and not as a specific procedure from which there will be no deviation.

## Request for Survey

The survey request may be originated by officers and leading petty officers of the engineering department, with the approval of the engineer officer. Normally, the request originates in the division of the department having custody of the material or equipment to be surveyed.

The initial survey request should be made in rough, on a survey form known as Survey Request, Report, and Expenditure (SandA Form 154). The initial survey request is shown in figure 17–4. The originator must include on or attach to the initial survey request a statement regarding the following:

1. Condition of the material
2. Cause or condition surrounding the loss, damage, deterioration, or obsolescence of the material
3. Responsibility for the cause or condition if such can be determined, or the reason why the responsibility cannot be determined


NAV. S. AND A. FORM 154 (Rev. 4-49)

SURVEY REQUEST, REPORT, AND EXPENDITURE

SHIP OR ACTIVITY: USS YAZOO (AN-92) — DATE: 4/6/53 — NO.:

REQUEST (To be prepared by supply officer, or head of Department)
It is requested that the items listed below be surveyed in accordance with Sec. 3, Chap. 19, N. R.

REASON: Lost overboard — APPROPRIATION: 1731601.28 S&FN — SIGNED:

ACCOUNT: 12228 — RANK: LCDR, USN.

| ITEM | QUANTITY | ARTICLE | IDENTIFYING MARKS, ETC. | DATE AND FROM WHOM RECEIVED | VALUES AT WHICH CARRIED |
|---|---|---|---|---|---|
| 1 | 1-EA | Cylinder, gas, acetylene, 225 cu. ft. | #72927 | | |

REPORT (To be prepared by head of Department, or by surveying officer(s) if so directed below)

| ITEM | CONDITION, CAUSE, RESPONSIBILITY, AND RECOMMENDATION | APPRAISED VALUE |
|---|---|---|
| 1 | Condition: Lost overboard 6 April 1953.<br>Cause: Lowering lines parted when cylinder was being lowered over ship's side into small boat.<br>Responsibility: J. W. Graham, BM2, in charge of working party, failed to examine line before using.<br>Recommendation: Disciplinary action for responsible party. Expend from records and replace. | |



**Figure 17–4.—The initial survey request.**

**4. Recommended disposition of the material and the action to be taken**

The description of the material should be as complete as humanly possible and should include serial numbers of the items involved, if applicable. Where the respective items are listed in the BuShips Allowance List, the group, page, and line numbers should be given. When applicable, any reference to BuShips *Manual* or other directives should be given in the initial survey request. This initial survey request should not be considered as the survey report, but as a guide to the CO in determining the type of survey (formal or informal) to be held. The initial request will also serve as an aid to the surveying officer, board, or department head, in the preparation of the survey report, in cases where the same survey form is used.

When the initial rough survey request has been approved by the engineer officer, it is forwarded to the supply office. The smooth survey request will be prepared by designated personnel in the supply office. Additional information from the supply department records will be noted (appropriation number, account number, date and source from which the material was received, and the value at which the material is carried).

The statement of the opinion of the originator, relative to the condition, cause, responsibility, and recommendation, will not be typed on the smooth survey report. However, this survey will be appended to the original of the smooth survey request and will be labeled "Originator's Statement." This will prevent confusion with the survey report as prepared by the designated surveying officer, board, or department head. After the smooth survey request is prepared, it is forwarded to the CO, or to his representative, for action.

## Action by CO

Upon receipt of the smooth survey request, the CO or his representative will determine whether a formal or an informal survey is appropriate. In case of formal surveys, the smooth survey request will be forwarded to the surveying

officer or board. In the case of informal surveys, the smooth survey request will be forwarded to the department head having custody of the material to be surveyed.

### Preparation of the Survey Report

The surveying officer, board, or head of department should make a thorough inspection of the material being surveyed, in order to determine the condition of the material. If the material is missing, a thorough examination of the circumstances surrounding the loss should be made and responsibility should be determined. If the cause and responsibility cannot be determined, an accurate and clear explanation should be made. Full information should be given in the report section of the survey request form, including the specific findings as to condition, cause, responsibility, and disposition. All pertinent information should be given to the surveying officer, board, or head of department, by persons concerned with the material under survey. The disposition of material should be in accordance with current directives and BuSandA *Manual*.

### Action by the Reviewing Officer

After action by the surveying officer or board, the survey report will be submitted for review to the CO, or to the officer ordering the survey (if the survey was ordered by higher authority). If the reviewing officer does not approve the survey report, he will require another survey to be held. In all cases the second survey should be a formal survey.

When required, survey reports should be forwarded to the cognizant bureau for final review and approval. In the absence of specific instructions, survey reports will be forwarded to BuShips for final review and approval.

### Survey Expenditure

Upon receipt of the properly approved survey form, the officer carrying the surveyed material on his records will take appropriate action. The material will be expended from the records and disposed of in accordance with the instructions of the survey. When disposition involves transfer to

another activity, the material will be transferred by means of an Expenditure Invoice (SandA Form 127) and an attached copy of the survey.

A record of all surveys is maintained by the supply office. In most cases, copies of all engineering department surveys are kept on file in the engineering log room.

In case of replacements of surveyed material, the original survey request, submitted by the department head, should be attached to the stub requisition.

## ALLOTMENTS

The commanding officer's responsibilities for taking up an allotment, keeping a current record of its status, and making the necessary reports and returns are usually delegated to the supply officer, but since the allotments are limiting factors on engineering department activities, its personnel must have a working knowledge of the procedure involved.

The funds appropriated for the use of BuShips in the maintenance, repair, and operation of the forces afloat are designated as "Ships and Facilities, Navy" (S & FN). BuShips allocates that portion of its maintenance funds for forces afloat to the fleet commanders and to ships, in the form of allotments. An allotment is an authorization to a naval activity to expend a predetermined sum for ordinary maintenance repairs and operation within the fiscal year for which granted. The allotments to the ships are published by BuShips as regular quarterly allotments. Commanding officers budget these quarterly allotments between the various departments of their ships to cover the cost of normal consumable materials, and of miscellaneous services necessary in the maintenance and operation of the ships. Allotments granted by BuShips are the principal funds used in the material operation and maintenance of any ship; these allotments do not cover fuel, provisions, ammunition, medical supplies, or pay.

BuShips allotments are charged with issues of both Naval Stock Account (NSA) and Appropriations Purchases Account (APA) material; however, APA charges are cost

charges only and do not reduce the available balance in the allotment. When material is of a standard nature and can be used for several purposes, it is purchased by funds from the Naval Stock Fund (NSF) and held NSA until it is issued for end use. When this material is expended to end use, a 5-digit end use expenditure account number is assigned. (For example, consumable general stores material issued to a battleship is expended to 13111.) At the same time, the appropriation of the bureau which draws the material is charged for it, and the NSF is credited for the amount of the charge; thus the NSF is referred to as a "revolving fund." The APA is a store-holding account in which the Navy holds material that has already been paid for by a specific appropriation. It is the nature of the material which primarily determines whether it shall be NSA or APA. Technical material designed for a specific purpose, such as a repair part for a main feed pump that could hardly be used for anything other than a main feed pump, is purchased by the Bureau or Supply Demand Control Point having material control. The purchasing activity pays for the material from its own appropriation.

Force and type commanders grant allotments from their budgets to repair ships and tenders for work (other than floating drydock) as required. Such allotments, which are charged to the ships being repaired, are recorded and handled by the repair ships and tenders separately from the allotments granted them for their own use. Repair ships and tenders receiving allotments for work on other ships maintain records of such allotments and make separate allotment and expediture reports thereon; again, this is the responsibility of the supply officer.

To enable the engineering department to maintain a current record of its allotment for repair, it is customary to obtain from the supply office a periodic statement which reflects the value of material issued to date, the unexpended balance, and the unobligated balance. With this record on hand, the engineering department can govern or budget its material requirements.

A similar periodic report is made by the supply officer to the CO, indicating the status of each department in the ship's regular quarterly allotment. This report is also important to the engineering department because the funds for maintenance of equipment and spaces are drawn from the quarterly allotment.

## SUMMARY

The engineering department is responsible for determining its requirements for general stores, repair parts, and equipage. The importance of correct stowage should not be underestimated. A few simple principles plus common sense form the basis of proper stowage. Reasonably enough, these principles stress such ideas as safety, accessibility, importance of inventory checks, and orderliness.

It is essential that personnel concerned know how to fill out a requisition for material or supplies. They should be familiar with in-excess and not in-excess requisitions.

The ship must operate within its quarterly maintenance allotment or request an increase, when necessary, from the type commander, for unusual expenditures. Equipage, supplies, and repair parts must be used wisely, since their replacement is chargeable to the ship's allotment.

## QUIZ

1. What three classes of material are used by the Navy?
2. What class of material used by the engineering department is listed in the general stores section of the *Catalog of Navy Material?*
3. What bureau has complete inventory control over General Stores Material items?
4. What publication will be useful in helping a CPO to distinguish between ordinary repair parts and BuShips Special Material?
5. On large ships, who has custody of all stock in drawer and shelf stowage?
6. How frequently should all equipage be inventoried?
7. When one officer relieves another as head of a ship's engineering department, which one is responsible for having an inventory made of equipage?

8. When should petty officers who are custodians of equipage hold an inventory with their reliefs?
9. When should the head of each department having cutody of machinery repair parts submit to the CO a running schedule of inventory of repair parts?
10. When should replacements for repair parts be requested?
11. On a small ship, what officer usually has custody of BuShips repair parts?
12. On board ships where repair parts are under the custody of the engineering department, repair parts are inspected and identified by what personnel?
13. Where are repair parts boxes generally located on small ships?
14. Aboard small ships, where can a duplicate set of keys to the locked repair parts boxes usually be found?
15. How are repair parts boxes identified on board ship?
16. When does the building yard furnish a new ship with a master stowage list of all repair parts boxes?
17. What requisition priority is assigned automatically when no priority is specified?
18. What requisition form is generally used when ordering material required for immediate expenditure for repairs or alterations?
19. Why should an MM1 or C have a general knowledge of the survey procedure?
20. Where does a survey request normally originate?
21. The originator of a rough survey request must make a statement of opinion relative to what 4 subjects, headings. or titles?
22. When should the initial survey request be forwarded to the supply office?
23. When a formal survey is to be held, the smooth survey request will be forwarded to which officer on board ship?
24. After the survey report has been made by the surveying officer or board, to whom is it submitted for review?
25. In the absence of specific instructions as to final review and approval, what is done with survey reports?
26. Where are copies of all engineering department surveys generally kept aboard ship?
27. Who authorizes and provides the principal funds to be used for the maintenance of ships?
28. Material that is of a standard nature and can be used for several purposes is purchased by funds from what appropriations?
29. What is the name of the store-holding account in which the Navy holds material already paid for by a specific appropriation?
30. Technical material designed for a specific purpose is usually purchased from what appropriation?

# CHAPTER 18

# ENGINEERING RECORDS AND REPORTS

## IMPORTANCE OF MAINTAINING RECORDS AND REPORTS

Engineering records and reports for the administration, maintenance, and repair of naval ships are prescribed by directives from higher authority, such as type commanders, BuShips, and CNO. These records and reports must be adequate and accurate, and must be kept up to date, in accordance with established standards.

Engineering paper work need not be complicated or difficult, provided that administrative and supervisory personnel have a good understanding of what is required.

Up to this time, as an MM3 and 2, you have been primarily concerned with operating logs and similar records. Now, as an MM1 or C, you will have new supervisory duties which will require that you have a greater knowledge of engineering paper work and the associated administrative procedures. An MM1 or C who believes that the responsibility for all engineering paper work belongs to the assistant engineer officer and the log room Yeoman is not fulfilling his duties as a supervisor. Supervisory duties and responsibilities require a knowledge of engineering records as well as such items as inspections, administrative procedures, training, preventive maintenance, and repair procedures.

Changes affecting the preparation and maintenance of records and reports are constantly being made. The type commander usually advises the ship of such changes, but

engineering department administrative personnel should also refer to BuShips *Journal*, Navy Department Bulletins, and BuShips *Manual* for additional information.

The basic data for engineering records and reports aboard ship originate in the machinery spaces. These data are required for all operations, repairs, alterations, casualties, material analyses, and various tests and inspections.

It should be kept in mind that the maintaining of records is not an end in itself, but a means to an end. In this chapter the discussion will be confined to the most common records and reports which apply directly to a ship.

## MACHINERY INDEX

The Machinery Index is a comprehensive listing of all machinery and equipment, other than electronic equipment, installed aboard ship. The data included in the index are required by BuShips to provide adequate repair parts, battle damage components, and replacement equipment to forces afloat. It is the basis for the maintenance of allowance lists, supply-demand reviews, and preparation of usage factors.

The Machinery Index is made up in the form of several large books, 10 by 15 inches in size. Each page is made up of various forms, containing machinery data, stapled to a blank sheet. The subject matter is arranged in accordance with the Navy filing system.

The Machinery Index is used as a reference book in obtaining name-plate data and other information on machinery and equipment installed on board ship. The Machinery History Cards are based on the information contained in the Machinery Index. When repair parts are requisitioned, the information required to fill out the repair parts data form is usually obtained from the Machinery Index.

Detailed instructions for preparing the Machinery Index can be found in the *Machinery Index Preparation, Maintenance and Revision Instructions*, NavShips 250–1800–1. This publication should be carefully studied in preparing and maintaining the Machinery Index.

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The Material (Machinery) History is a record of all repairs, alterations, inspections, derangements, measurements taken, parts renewed, name-plate data, length of time that units have been used, file numbers of letters, and other pertinent data on each machinery unit.

The Material History that is kept correct and up to date is the most valuable record found in the engineering department. However, when this record is neglected it will cause unnecessary difficulties and hardships in trying to keep an adequate material maintenance program for the engineering department. The Material History is of primary importance to personnel who supervise repair work; it is also of concern to supervisory personnel responsible for maintaining it, since these records are inspected when formal administrative and material inspections are held on board ship. The following cards are available for maintaining the Material History:

| *Form No.* | *Name* |
|---|---|
| NavShips 527 | Machinery History |
| NavShips 527A | Electrical Machinery History |
| NavShips 528 | Unit Record Card |
| NavShips 529 | Repair Record Card |
| NavShips 530 | Alteration Record Card |
| NavShips 531 | Megger Test Record |
| NavShips 532 | Blank Utility Card |
| NavShips 533 | Bearing Record |
| NavShips 536 | Electronic Equipment History Card |
| NavShips 537 | Record of Field Changes |
| NavShips 538 | Tube Performance Record |
| NavShips 539 | Hull History Card |

The above is a complete list of Material History Cards. The MM will not be required to use the electrical cards (NavShips 527A and 531), nor the electronics cards (NavShips 536, 537, and 538). Therefore, these cards will not be discussed in this training course.

Of the above-listed cards, four form the basis of the ship's

Material History: Machinery History, Electrical Machinery History, Electronic Equipment History, and Hull History.

### Machinery History Card

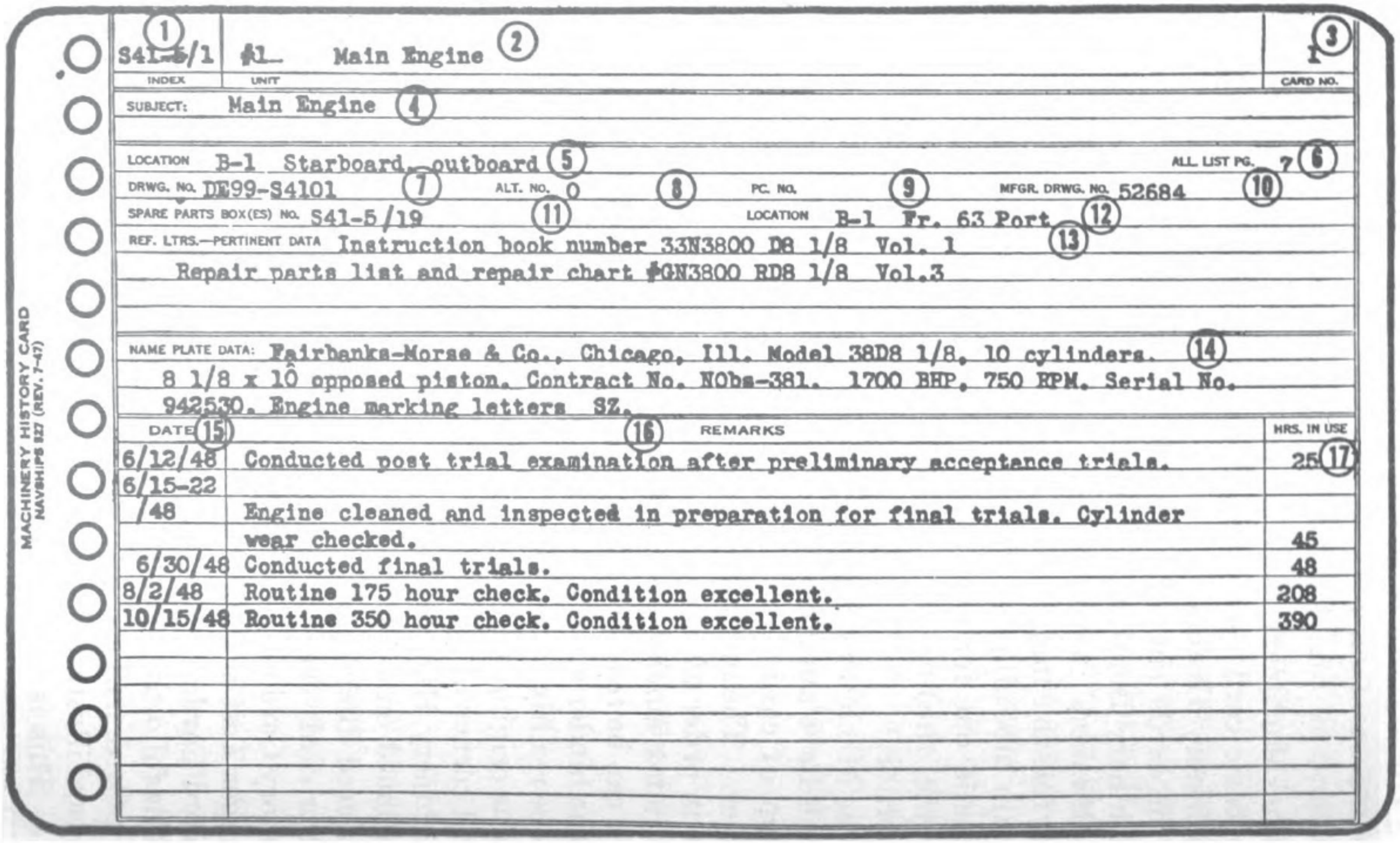
The Machinery History Card, shown in figure 18–1, is the basic card used to set up or to revise the Material or Machinery History records. The sequence of arrangement of the cards (in regard to subject matter) is based on the Machinery Index, which is, in turn, based on the *Navy Filing Manual.* A card is made out for each unit of machinery and for the major component parts. Take, for example, a main lube oil pump. A separate Machinery History Card is made out for each item in the following order: pump, turbine, throttle valve, lube oil cooler, reduction gear, and governor.

The Machinery History Cards are placed in large binders, which have a number of dividing fiber sheets with tabs. A group of cards is arranged for each dividing sheet of the binder. The individual cards are arranged from top to bottom in order of their respective index numbers. This leaves the index number and title of each card visible, so that any card can be readily located. The tabs on the dividing sheets in the binder are also numbered, so that each group of cards can be readily found.

The original card is numbered 1, as shown in the top right-hand corner of figure 18–1. When the space for "Remarks, Machinery History" has been filled on this card, entries are continued on a blank Utility Card, numbered 2. This card is placed directly behind the basic Machinery History Card. Other cards that are placed in back of the basic Machinery History Card are: Bearing Record Card, Unit Record Card, Megger Test Card, Alteration Record Card, and the Repair Record Card.

The following information is found on the Machinery History Card. (The numbers correspond to those encircled on the card illustrated in figure 18–1.)

1. This is the Machinery Index number of the unit for which the card is prepared.



MACHINERY HISTORY CARD
NAVSHIPS 527 (REV. 7-47)

| INDEX | UNIT | CARD NO. |
|---|---|---|
| 1 S41-5/1 | #1 Main Engine 2 | 1 3 |

SUBJECT: Main Engine 4

LOCATION B-1 Starboard, outboard 5 ALL LIST PG. 7 6
DRWG. NO. DE99-S4101 7 ALT. NO. 0 8 PC. NO. 9 MFGR. DRWG. NO. 52684 10
SPARE PARTS BOX(ES) NO. S41-5/19 11 LOCATION B-1 Fr. 63 Port 12
REF. LTRS.—PERTINENT DATA Instruction book number 33N3800 D8 1/8 Vol. 1 13
Repair parts list and repair chart #GN3800 RD8 1/8 Vol.3

NAME PLATE DATA: Fairbanks-Morse & Co., Chicago, Ill. Model 38D8 1/8, 10 cylinders. 14
8 1/8 x 10 opposed piston. Contract No. NObs-381. 1700 BHP, 750 RPM. Serial No.
942530. Engine marking letters SZ.

| DATE 15 | REMARKS 16 | HRS. IN USE |
|---|---|---|
| 6/12/48 | Conducted post trial examination after preliminary acceptance trials. | 25 17 |
| 6/15-22/48 | Engine cleaned and inspected in preparation for final trials. Cylinder wear checked. | 45 |
| 6/30/48 | Conducted final trials. | 48 |
| 8/2/48 | Routine 175 hour check. Condition excellent. | 208 |
| 10/15/48 | Routine 350 hour check. Condition excellent. | 390 |

Figure 18-1.—Machinery History Card.

2. This entry gives the number and the name of the unit.

3. The number placed in this space will be "1" on all original cards in the set. Subsequent (utility) cards will be numbered consecutively.

4. This space was originally intended for the subject unit of the card. It is no longer used, as the subject now appears in space No. 2.

5. This entry gives the name and number of the compartment in which the unit is located.

6. In this space is entered the number of the pages on which the unit is listed in the BuShips Allowance List.

7. This is the BuShips plan number for the unit, or the first plan of a series of plans for the unit.

8. This space is for the alteration number on BuShips plans.

9. This space is normally left blank. An entry here would represent the piece number.

10. This is the manufacturer's drawing number.

11. This is the repair parts box(es) number. If necessary, the list of repair parts boxes and their location can be typed in the "Remarks" space.

12. This entry gives the location of repair parts.

13. This space is for pertinent data such as the file numbers of any letters concerning operation and maintenance; repair parts allowance; manufacturer's instruction book number.

14. This entry is the name-plate data of the unit. (This data should be copied from the Machinery Index.) When necessary, this data can be recorded in the "Remarks" column.

15. Date entries made here refer to the data in the "Remarks" column.

16. The "Remarks" column is for recording tests, inspections, repairs, alterations, casualties, material analysis data, and the like.

17. These entries specify the total number of hours the machinery has been in use at the time of the respective entry in the "Remarks" column.

The reverse side of the card is a continuation of the lower part of the card.

### Unit Record Card

The Unit Record Card is used to record measurements of reciprocating machinery such as internal combustion engines and reciprocating pumps. It can be used for any unit that has pistons and cylinders. This card is placed behind the Machinery History Card of the specific unit.

### Bearing Record Card

A Bearing Record Card is provided to record bearing measurements of each bearing unit. These cards are inserted in the Material History binder behind the applicable history card.

## CURRENT SHIP'S MAINTENANCE PROJECT

The Current Ship's Maintenance Project (CSMP) serves as a precaution that no work item will be overlooked; it makes possible the orderly scheduling of work requests for an overhaul period; and it ensures that the detailed information required for each repair job will be readily available. CSMP items are written up for important ship's force repair work as well as for repair ship, tender, and naval shipyard work.

The CSMP is made up of the following three cards: Repair Record Card (blue), Alteration Record Card (pink), and Record of Field Changes (white). Record of Field Changes cards are used in connection with authorized alterations of electronic equipment and therefore will not be discussed in this training course. The CSMP cards are the only cards that have a short extension—called a "tab"—at the upper left-hand corner.

When a repair item becomes evident or when an authorized alteration is received, a CSMP card should be filled out and placed in the Material History binder, behind the proper Machinery History Card. The distinctive color of these CSMP cards makes it a simple matter for the CPO checking

the Material History to see what work is outstanding. When the work item has been completed and a proper notation has been made on the Machinery History Card, the CSMP card should be removed from the binder and placed in a "completed work" file.

When a ship is scheduled for a repair availability, the CSMP is used to determine the repair work and alterations to be accomplished. The CSMP work items are then reviewed, and the relative importance decided upon. The cards are arranged in the order of priority, and individual work request numbers are assigned. The appropriate number of copies of the work requests are typed by the Engineer's Yeoman. This is the common procedure, except for naval shipyard routine overhauls of vessels in the Atlantic Fleet.

From your experiences as a Machinist's Mate, you can understand why it is very important to record all necessary repair jobs on the CSMP cards. Otherwise small but important repair jobs, which should be accomplished during the overhaul period, may be overlooked or forgotten. The CSMP repair cards should be made out as soon as a defective material condition is discovered. Then the details will be fresh in your mind and a complete description of the conditions, and the required repairs, can be written up. This will ensure sufficient information which will prevent delays or misunderstanding at a later date. A good CSMP must have all the detailed information and a complete list of all the required repair items.

As an MM1 or C, you should be capable of writing up, in rough, a Repair Record Card which gives the required information on material conditions and required repairs, with reference to applicable blueprints. The remaining information needed for the Repair Record Card can be filled in by the log room personnel.

### Repair Record Card

The Repair Record Card (fig. 18–2) is used to keep a record of all repairs that are pending. This card is inserted behind the appropriate Machinery History Card. The

blue-colored tab extends above the Machinery History Card. The CSMP Repair Record Card is filled out, giving all the required information and data, as soon as a repair item or job becomes known. A separate card is made out for each item in need of repairs. However, small items that are similar (valves, for example) are usually included on one card. The Repair Record Cards are kept on file until the indicated repairs have been completed.

Entries on this card are as follows: (Numbers correspond with those encircled on the card shown in figure 18–2.)

1. For engineering department purposes, the "X" will indicate the type of repair work—mechanical, electrical, or hull.

2. Number and name of the unit on which the repair is to be made. This information can be obtained from the corresponding Machinery History Card.

3. Index number, taken from the corresponding Material History Card, for the unit to be repaired.

4, 5, and 6. An "X" entered on one of these spaces indicates the priority of the repair—whether the repair is deferred, routine, or urgent. This priority is assigned by the ship.

7. Location of the unit to be repaired. The compartment name and number should be given. Where necessary, the location in the compartment and frame numbers are given.

8. Date the card is started; this should be the date when the repair is noted as being necessary and the card is made out.

9. Originally, this space was provided for the title to which a repair was charged. This information is no longer applicable, and the space is left blank.

10, 11, and 12. An "X" entered on one of these spaces indicates whether the work is to be performed by the ship's force, by the repair ship, or by the naval shipyard.

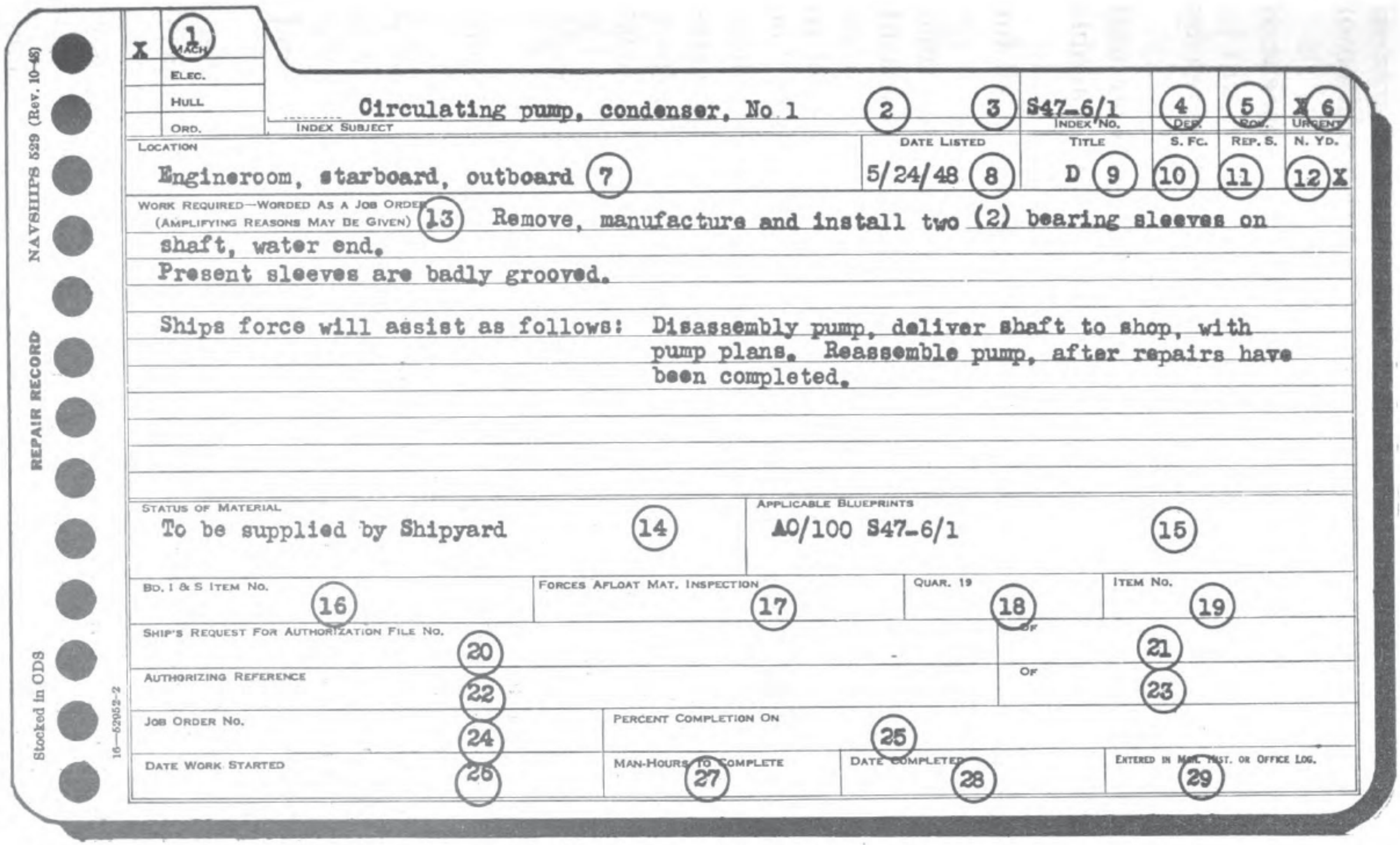



Figure 18–2.—Repair Record Card.

13. This is written up so that it will cover the following information:

a. A detailed description of the defective condition or malfunctions
b. The required repair work, including replacement of parts
c. Where applicable, assistance that will be given by ship's force
d. When necessary, reference to subject matter and plans in manufacturer's instruction book available on board ship
e. The name of the individual who can be contacted for additional information in regard to the job.

If the space (No. 13) allowed for this entry is not sufficient, the information should be continued on the back of the card.

14. In this space is indicated the status of material to be used for the repair, such as "on board," "at shipyard," or "en route to ship from supply depot." If the naval shipyard is designated to do the work, it will furnish the material. When a tender or repair ship is designated, the repair activity will furnish such material as is carried in stock. In most cases the ship requesting repairs will have to furnish the repair parts. If repairs are to be made by the ship's force, the material will be requisitioned by the ship.

15. Give the BuShips plan number of the applicable blueprints that may be required to accomplish the repair job.

16. Give the Board of Inspection and Survey item number, if such an inspection has been held. This number is entered on the Repair Record Card when a list of repairs is made for an inspection by the Board of Inspection and Survey.

17. Give the title of the type, or force, commander convening a forces afloat material inspection, if such an inspection has been held.

18. Give the number of the quarter and the year in which the forces afloat inspection was held.

19. Give the forces afloat material inspection item num-

ber, when applicable. This number is entered on the Repair Record Card when a list of repairs is made up for a material inspection.

20. Give the file number of any letter that may have been received or written in regard to the repair item. A copy of this letter, when sent, is placed in the log room file.

21. Give the date of such a letter (No. 20).

22. Give the file number of the letter in reply to a letter that may have been written (No. 20).

23. Give the date of such a letter (No. 22).

24. Give the naval shipyard or repair ship job order number, when assigned by the repair activity where the repair work is to be accomplished.

25. In cases where the repair job has not been fully completed, give the date and percentage of completion for reference for the next shipyard, or repair ship, availability.

26–29. These spaces are self-explanatory.

## Alteration Record Card

The Alteration Record Card, shown in figure 18–3, is used to record all authorized alterations pending. While an alteration is pending, the card is placed behind the Machinery History Card of the unit affected, with the pink tab extending above the top of the history card. The information and data are obtained from the SHIPALT (NavShips 99) and from BuShips letters that authorize alterations equivalent to repairs, and from BuShips letters that may be received regarding an alteration. The use of these Alteration Record Cards facilitates the listing of required information for alterations in the CSMP which, in turn, is maintained with the Material History.

Entries that should appear on this card are based on information contained in the SHIPALTS which are sent to the ships concerned and are similar to those on the Repair Record Card. There is this difference in recording information on the two cards: the Repair Record Card is made out when the need for a repair becomes evident, or when it is decided that

a repair should be undertaken at a future date; the Alteration Record Card, on the other hand, is filled out upon receipt of the approved SHIPALT. The entries for the Alteration Record Card are as follows:

1. Priority assigned by the ship.

2. Name of the bureau having cognizance of the alteration; this is always listed as "Ships" for the engineering department CSMP since alterations will be mechanical, electrical, or hull.

3. Number and name of the unit on which the alteration is to be done.

4. Index number of the unit; this number, as well as the index subject, will be assigned in accordance with instructions in the *Navy Filing Manual*. The number gives the location of the CSMP Alteration Record Card in the Material (Machinery) History. The number and name are the same as the ones used on the corresponding Machinery History Card.

5, 6, and 7. An "X" entered in one of these spaces indicates the priority of the alteration, whether deferred, routine, or urgent. This is the priority assigned by the ship except in some cases where a certain priority may be recommended by a higher authority, such as a type commander.

8. Name and number of the compartment in which the unit is located.

9. Date of the alteration. This date is copied from the SHIPALT (special form, NavShips 99) or from the authorizing letter.

10. Title to which the alteration is charged; this information is also obtained from the SHIPALT or from the authorizing letter.

11, 12, and 13. An "X" entered in one of these spaces indicates who is to perform the work—whether the ship's force, the forces afloat (repair ships or tenders), or the naval shipyard. This information is also obtained from the SHIPALT or from the authorizing letter.

14. Brief description of the work to be done.

15. Status of the material to be used for the alteration.

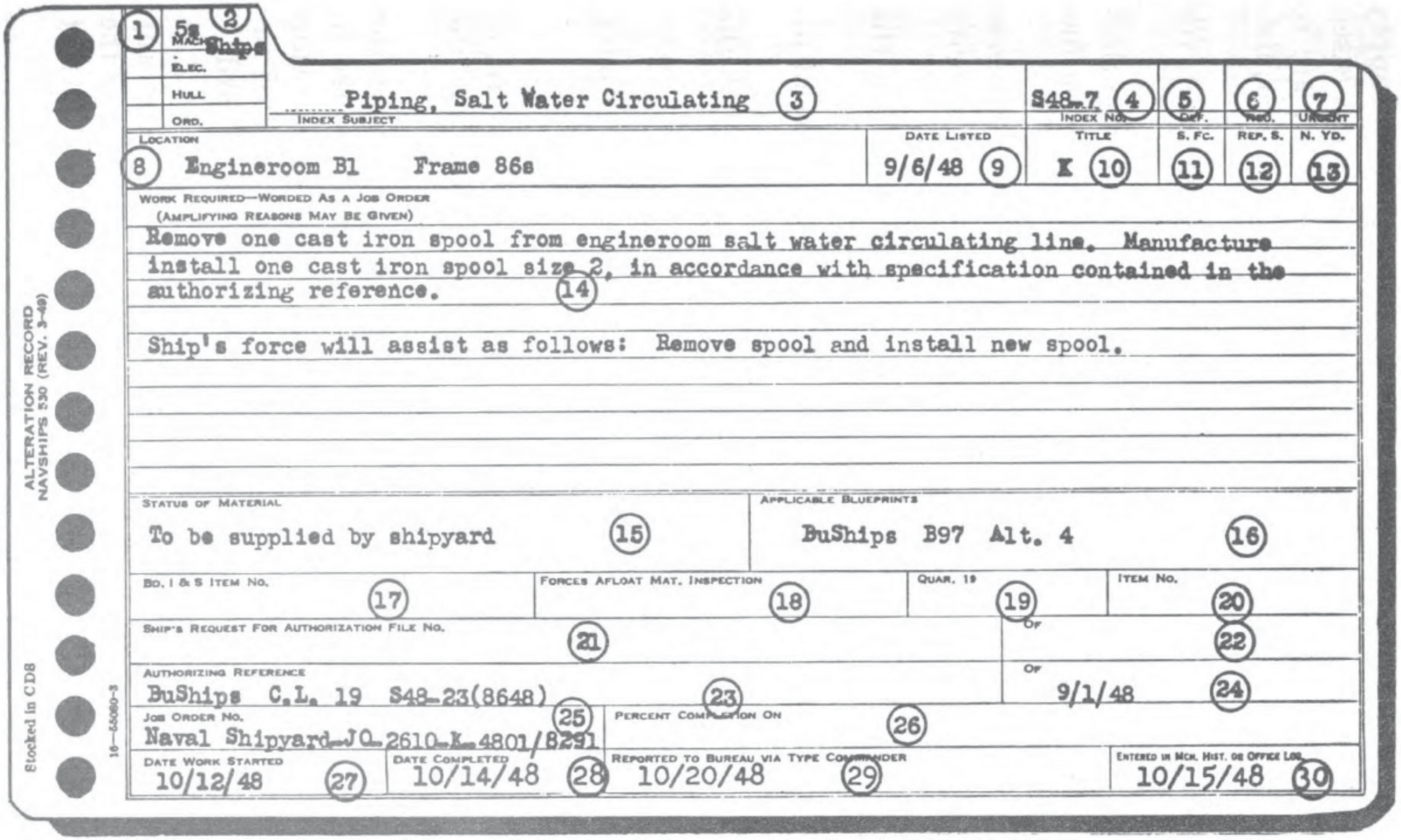



Figure 18-3.—Alteration Record Card.

The SHIPALT or the authorizing letter will indicate who is to do the work (see numbers 11, 12, and 13). If a naval shipyard is designated to do the work, it will also supply the material. Tenders and repair ships will, in most cases, furnish the required material. For alterations that are to be accomplished by the ship's force, the material is requisitioned by the ship.

16. BuShips plan number of the applicable blueprints for the alteration.

17. Item number from the Board of Inspection and Survey list of authorized alterations, if such an inspection has been held.

18. The title of the type commander convening a forces afloat material inspection, and any recommended priority made by such inspection.

19. Number of the quarter and the year in which the forces afloat material inspection was held.

20. The item number from the forces afloat material inspection list of recommended alterations.

21. File number for a repair activity to accomplish the approved alteration.

22. The date of any such letter (No. 21).

23. The number of the SHIPALT, or the letter authorizing the alteration to be accomplished.

24. Date of the SHIPALT or the letter (No. 23).

25. Job order number assigned by the naval shipyard, or repair ship, when the work has been undertaken by the activity.

26. In cases where the work has not been completed, the date and the percentage of completion should be entered in this space for reference for the next shipyard or repair ship (or tender) availability. In some cases more detailed information must be given on the reverse side of the card.

27–30. These items are self-explanatory.

Reverse side of card. The back of the card is used for any additional information that may be necessary. Where the detailed description of the work is lengthy (see No. 14), it is continued on the reverse side.

## REQUEST FOR ALTERATIONS

It is sometimes difficult to obtain authorization for an alteration; a request for one entails a great deal of Navy correspondence, and may involve a period of several months. A definite policy has been set up to prevent the addition of weight to naval ships by unnecessary or unimportant alterations. Instructions regarding the procedures for requesting approval of new alterations are issued by the type commanders. In general, the procedure is as follows:

1. Requests should be submitted as soon as the need for the change has been fully investigated.
2. An alteration request should contain details, including any defects or unsatisfactory conditions of the present installation, advantages of the proposed alteration, name-plate data, or other information for proper identification, reference to applicable blueprints, sketches of proposed changes, etc.
3. If the alteration involves a change of weight, and vertical moment above the keel, compensation for the proposed alteration should be specified and appropriate statements made in regard to any change of weight or of vertical moment. When there will be no such changes, the fact should be stated.
4. If the proposed alteration should result in a reduction of space for accommodation of the crew, details of the reduction of space and the reasons for accepting this loss should be included.
5. Requests should be forwarded in the following manner:
    a. Commanding officers should submit requests via their unit commander, with sufficient copies for the required distribution.
    b. The squadron commander (when applicable) should forward the original and sufficient copies of the request to the type commander, including appropriate comments in his endorsement. Copies of the request should be furnished to all like commands.
    c. Recipients of these copies should investigate the

proposed alteration and submit their recommendations to the type commander.

d. The type commander should forward the request to the appropriate bureau with his recommendations and a statement as to other ships of his force.

## ENGINEERING LOG

The *Engineering Log* (NavShips 117), shown in figures 18–4, 18–5, and 18–6, is a complete daily record, from midnight to midnight, of important events and data pertaining to the engineering department and the operation of the ship's propulsion plant. An engineering log should be maintained by each ship in commission, and by such other ships and craft as may be designated by competent authority.

The original rough log constitutes a legal record and no erasures may be made in it. If an error is made, a single line should be drawn through the original entry and the correction inserted below. Corrections, additions, or changes should be made only by the person required to sign the record for the watch, and should be initialed by him on the margin of the page. After the log has been signed by the CO, no change should be made without his permission or direction.

The Engineering Log is kept in the control engineroom while the ship is under way, and in the steaming engineroom or in the engineering log room, when in port. This log is generally filled out by the MMC of the watch, or the MMC assigned to the day's duty.

On large ships, the log is signed by the engineering officer of the watch, or the engineering duty officer, before he goes off duty. The engineer officer inspects and approves the Engineering Log of the preceding day. On the last calendar day of each month, the CO signs the log.

The following information must be entered in the Engineering Log:

1. Name of the ship, date, and place where the ship is moored or anchored, or its route
2. Average hourly rpm of each shaft

Engineering Log—All Surface Vessels
NAVSHIPS (NBS) 117
(Revised 4-46)

§ Page 1

# ENGINEERING LOG

*U. S. S.* Speedwell, CV-3333 *Date* 21 Feb. 1949

At or en route from N.O.B., Norfolk, Va. to Sea

**TABLE 1**

| Hour Ending | Average* R. P. M., All Shafts | Speed* in Knots from R. P. M. | Hour Ending | Average* R. P. M., All Shafts | Speed* in Knots from R. P. M. |
|---|---|---|---|---|---|
| 0100 | | | 1300 | | |
| 0200 | | | 1400 | 12.3 | 1.6 |
| 0300 | | | 1500 | 105.2 | 14.3 |
| 0400 | | | 1600 | 93.3 | 12.7 |
| 0500 | | | 1700 | 119.3 | 16.1 |
| 0600 | | | 1800 | 120.0 | 16.3 |
| 0700 | | | 1900 | 120.0 | 16.3 |
| 0800 | | | 2000 | 120.0 | 16.3 |
| 0900 | | | 2100 | 120.0 | 16.3 |
| 1000 | | | 2200 | 120.0 | 16.3 |
| 1100 | | | 2300 | 120.0 | 16.3 |
| 1200 | | | 2400 | 120.0 | 16.3 |
| ** | | | ** | | |

| TABLE | 2 | 3 | 4 |
|---|---|---|---|
| Item | Fuel (Gallons fuel oil and diesel oil, or tons* coal) | Water (Gallons) | Lubricating Oil (Gallons) |
| Brought forward, at 0000 | 1,930,766 | 279,662 | 6,299 |
| Received to-day | | 15,800 | |
| Increase by inventory | | | |
| Distilled to-day | x x x | 30,100 | x x x |
| Total Receipts | 1,930,766 | 325,562 | |
| Expended, Eng. Dept. | † 25,305 | †† 28,715 | ††† |
| Expended, boats | | | |
| Expended, galley and ship | ‡ | ‡‡ 61,497 | x x x |
| Expended, by inventory | | | |
| Total Expended | 25,305 | 90,212 | |
| On hand, 2400, to-day | 1,905,461 | 235,350 | 6,299 |

**Table 5**

0815 Daily
¶ Displacement: Forward 29 - 10 / 29 - 10 aft 29 - 6 / 29 - 6 mean 29 - 8 / 29 - 8 tons 38,200 / 38,200

⊕ Miles: (0000-2400) ........; ***Engine miles (0000-2400) 158.8 Days out of dock 233

**REMARKS**

(See Instructions on reverse side)

Time zone description -5; clocks set back or ahead ...... hrs. ...... min. at ......

00-08 Moored starboard side to pier 5 at Naval Operating Base, Norfolk, Virginia, with following services from dock: Telephone and fresh water. Following machinery in operation: #6 boiler with 600 p.s.i., 725° superheat, #5 main feed pump, #11 forced draft blower, #3 electric fuel oil service pump, fuel oil suction B54F, standby B53F, #6 and #8 fire pumps, #6 fuel oil heater, #2 auxiliary booster pump, make-up feed from B954W, standby B944W, #3 generator, #2 motor generator, #1 M.P. air compressor, #2 ice machine, forward and aft gyro compasses, #1 distilling plant distilling to B944W. Following machinery out of commission: #3 M.P. air compressor and aft boat crane. @ 0145 secured #1 distilling plant, @ 0522 permission granted and blowed tubes on #6 boiler, @ 0635 started #1-#2 H.P. air compressors. Carried out regular in port watch routine tests and inspections. Conditions normal.

(Signed) G. J. Perron, Lt.(j.g.)

* To tenths; use whole numbers for other items.
** Blank space for data when clocks are set back.
*** From Table 1 (sum of hours times engine speeds).
† Fuel burned in boilers.
†† Water used as "make-up feed."
††† Lubricating oil used on ship's machinery.
‡ Fuel burned in galley.
‡‡ Potable water expended from ship's tanks, or for ship's purposes
¶ On getting under way and anchoring
⊕ Total distance through water (NOT distance made good) from navigator's data.
§ Begin a new series of page numbers each calendar year

USE EXCEPTIONAL CARE TO WRITE THIS LOG LEGIBLY AND KEEP IT CLEAN

Figure 18–4.—Engineering Log, page 1.

Page 2

**REMARKS—Continued**

08-16 As before except, @0825 cut in steam and drain to siren and whistle, @0900 placed aft boat crane in commission, @ 0930 started warming up #4 generator on auxiliary steam, @ 1015 secured #1 H.P. air compressor and start #2 H.P. air compressor, @ 1016 placed auxiliary steam line port side A.E.R. back in commission, @ 1035 paralleled #3 and #4 generators, @ 1040 started #2 D.C. motor generator and secured #1, @ 1041 set aft Diesel generator on automatic operation, @ 1050 set forward Diesel generator on automatic operation, @ 1050 completed testing all underway I.C. circuits, @ 1120 placed #1 fire pump out of commission, @ 1121 completed testing anchor windlass, steering gear and all heavy deck electrical gear, @ 1130 completed jacking over all idle machinery by hand when possible, @ 1130 stationed steaming watch in all engineering spaces as needed, @ 1145 lighted fires under #3, 4, 7 and 8 boilers, @ 1146 started to lower superheat in #6 boiler, @ 1146 engaged jacking gear in #1, 2, 3, and 4 main engines, started main engine lube oil pumps, @ 1210 secured superheater in #6 boiler, @ 1212 stationed smoke watch, @ 1300 stationed anchoring, mooring and special sea detail, @ 1304 lifted safety valves by hand on #3, 7 and 8 boilers, @ 1306 lifted safety valves by hand on #4 boiler, @ 1312 cut #3, 7 and 8 boilers in on the auxiliary steam line, @ 1316 cut #3 boiler in on the main steam line, @1320 cut #8 boiler in on the main steam line, @ 1323 cut #4 boiler in on the auxiliary steam line, @1324 cut #4 boiler in on the main line, NOTE: #7 boiler was warmed up with the main steam stop open, @ 1328 completed testing main engines, @ 1329 reported engineering department manned and ready to answer all bells, @ 1330 secured #6 boiler, NOTE: @ 1320 paralleled #2, 3 and 4 generators, @ 1322 secured #3 generator electrically, @ 1329 secured #3 generator, @ 1330 reported condition yoke set in engineering department, @ 1339 put #2 fire pump out of commission, @ 1403 completed setting safety valves on #6 boiler at prescribed pressures, witnessed by Ch. Mach. C. T. Cavignac, @ 1406 started #7 fire pump, secured #6 fire pump, @ 1408 started #3 H.P. air compressor, @ 1420 shifted and cleaned lube oil strainers, @ 1444 lighted fires under superheaters in #7 and 8 boilers, @ 1445

Con't Page 3

REMARKS {are / are not} CONTINUED on Additional Sheet (N. B. S. 110), Page No. 3 Initials #DB.

**INSTRUCTIONS**

The Engineering Log may be written with pencil or pen, as most convenient. The ORIGINAL writing is the LEGAL RECORD and must be preserved. It is not necessary to make a copy except when one or more pages are sent away from a ship in commission.

Table 1 and the REMARKS must be written at the time events occur. Other tables may be written before noon the following date.

REMARKS shall be written by "watches" underway; and by "day's duty" at anchor. They shall be signed by the Engineer Officer of the Watch or Day before going off duty.

Remarks shall be a chronicle of important events. They shall include: First, boilers in use; second, engine combination in use; third, major speed changes, such as "one-third," "standard," "full"; fourth, casualties to personnel or material within or under the cognizance of the engineer department; fifth, special entries required by Navy Regulations, Bureau of Ships' Manual and letters of the Bureau of Ships.

ALTERATIONS OR ERASURES IN THE REMARKS ARE NOT PERMITTED. NECESSARY CORRECTIONS SHALL BE MADE BY A NOTE IN THE REMARKS.

**DISPOSITION**

This log is to be retained on board and forwarded to the Bureau at the end of 2 years, or on decommissioning. See U. S. Navy Regulations, 1920, Articles 907 (2) (d) and (e).

APPROVED:

________________ U. S. N., Commanding.
(Rank)
(To be signed once a month on log of last day or on detachment)

CORRECT:

C D Smith Lt U. S. N., Engineer Officer.
(Rank)
(To be signed by noon of following date)

Figure 18–5.—Engineering Log, page 2.

Page 3

U.S.S. Speedwell, CV-3333 Date 21 Feb. 1949

lighted fires under superheater #3 and 4 boilers, @ 1515 started #2 distilling plant, distilling to feed bottoms, @ 1520 completed blowing tubes in #3, 4, 7 and 8 boilers with the O.O.D.'s permission, @ 1524 fire drill in the ward room, @ 1524 started #5 fire pump, @ 1531 secured from anchoring, mooring and special sea detail, @ 1534 secured from fire drill, @ 1535 general quarters, @ 1540 shifted to cruising control, @ 1545 split the plant, split the electrical load, S/S 15 knots, 113 R.P.M., making 113 R.P.M., @ 1555 secured from general quarters, carried out underway routine tests and inspections, made speed changes as per engineer's bell book, lube oil in sumps as follows: #1 - 1080, #2 - 1000, #3 - 1000, #4 - 1080.

(Signed) H. D. Britcher, Lt.(j.g.) USN

16-20 Steam as before except, @ 1600 secured #5 fire pump, @ 1625 put #1 and 2 fire pumps in commission, @ 1635 shifted distillate from feed bottom to ship's tanks, @ 1700 set condition yoke, @ 1730 started #5 fire pump, @ 1745 secured #5 fire pump, @ 1800 shifted and cleaned lube oil strainers, @ 1825 secured smoke watch, @ 1836 shifted M.U.F. to B949W, standby B948W. Lube oil in sumps as follows: #1 - 1100, #2 - 1050, #3 - 1000, #4 - 1100, @ 1940 raising superheat from 825° to 850° at 10° per minute. Carried out regular underway routine tests and inspections.

(Signed) G. J. Perron, Lt.(j.g.)

20-24 Steaming as before except as follows: @ 2015 completed splitting 150 lb. auxiliary steam with #1 and 2 reducers in use, @ 2020 lighted off #1 evaporator unit, @ 2030 permission granted and blowed tubes on boilers #3, 4, 7 and 8, @ 2230 shifted and cleaned lube oil strainers, @ 2230 shifted M.U.F. from B-948W, standby B-944W, @ 2300 put #3 H.P. air compressor back in commission. Lube oil in sumps as follows: #1 - 1075, #2 - 1050, #3 - 1025, #4 - 1075. Carried out regular underway tests and inspections.

(Signed) R. P. Metzger, Ens., USN

C. D. Smith, Cdr.

Figure 18-6.—Engineering Log, page 3.

3. Average knots for each hour, as computed from latest approved speed and rpm tables

4. Major speed changes, such as "one-third," "standard," and "full"

5. New standard speeds, if such are initiated, and the time that the speed changes were made

6. Engine combinations in use

7. Boilers in use

8. Fuel oil, fresh water, and lube oil on hand at midnight, and the amounts received and used during the preceding 24 hours

9. Table of draft, displacement, knots (midnight to midnight), engine miles steamed, and the number of days out of drydock

10. Any special entries required by *Navy Regulations*, BuShips *Manual*, or letters from BuShips

11. Record of casualties to personnel or material in the engineering department

12. Remarks of the engineering officer of the day or watch

Entries in the Engineering Log should be made in accordance with instructions on the log form and as further outlined in chapter 10, section 4, of *Navy Regulations*, and in BuShips *Bulletin of Information* No. 16.

The remarks column of the log should be written up neatly, legibly, in complete statements, and with the use of standard phraseology. Watches are headed 0–4, 4–8, 8–12, etc. The midwatch should give the complete status of the engineering plant, including the boilers in use and the fuel oil and feed water tanks supplying them, the auxiliary machinery and generators in use, the standby fuel oil suction and make-up feed tanks, and the machinery not in commission. Any change in the status of a machinery unit or tank, and the time the change occurs, is also entered in the log. The phrases "under way as before", "standing by as before", or "moored as before" may be used for all watches except the midwatch. The Engineering Log should not be folded or creased, and it should be kept clean and free of grease.

## ENGINEER'S BELL BOOK

The Engineer's Bell Book, shown in figures 18–7 and 18–8, is an official legal record kept of the time any bell, signal, telegraph, or other form of order regarding change in the movement of the propellers is received at the control station of each of the main engines (column 1); the interpretation of each order (column 2); the actual propeller rpm resulting

Engineer's Bell Book—All Vessels
NAVSHIPS (NBS) 116

### ENGINEER'S BELL BOOK

(SEE INSTRUCTIONS ON REVERSE SIDE)

U. S. S. Speedwell-CV3333 Shaft No(s). 1 Date April 18, 1954
En route from New York, New York to Sea

Record of all "bells," signals, and orders received regarding movement of propellers this date.

TIME ZONE DESCRIPTION +5 Clocks set back or ahead ........ hrs. ........ min., at ........

| (1) TIME | (2) SIGNAL | (3) R. P. M. | (4) COUNTER | (1) TIME | (2) SIGNAL | (3) R. P. M. | (4) COUNTER | (1) TIME | (2) SIGNAL | (3) R. P. M. | (4) COUNTER |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0843 | TEST | | 572870 | 1132 | 1/3 | 37 | 585060 | 1740 | I 95 | 155 | 617191 |
| 0847 | Reported Bar | | 572983 | 1138 | 2 | | 585280 | 1741 | 2/3 74 | 135 | 617270 |
| 0900 | Counter | | 572990 | 1139 | 1/3 | 37 | 585310 | 1744 | 2/3 57 | 57 | 617350 |
| 0916 | B 2/3 | 84 | 573000 | 1139 | 2 | | 585330 | L. A. Comm Lt. (jg) | | | |
| 0917 | 2 | | 573040 | 1145 | 1/3 | 37 | 585370 | 1759 | 2/3 74 | 74 | 618606 |
| 0917 | B 2/3 | 84 | 573060 | 1146 | 2/3 | 74 | 585390 | 1800 | hour | | 618620 |
| 0918 | 2/3 | 74 | 573110 | 1147 | I | 110 | 585470 | 1801 | I 95 | 95 | 618669 |
| 0919 | B 1/3 | 44 | 573130 | F. P. Gutteridge | | | MMC | 1803 | I 110 | 110 | 618852 |
| 0919 | II | 148 | 573140 | R. L. Hooten | | | | 1809 | 2/3 74 | 80 | 619552 |
| 0920 | B II | 124 | 573200 | 1200 | Counter | | 586970 | 1811 | 2/3 66 | 66 | 619674 |
| 0921 | B 1/3 | 44 | 573240 | 1236 | 2/3 72 | 72 | 590930 | 1812 | 2/3 74 | 74 | 619786 |
| 0921 | B 2/3 | 84 | 573300 | 1242 | 2/3 77 | 77 | 591370 | 1816 | 2/3 72 | 72 | 620099 |
| 0922 | B II | 124 | 573360 | 1250 | 2/3 85 | 85 | 592000 | 1819 | 2/3 70 | 70 | 620771 |
| 0922 | 2 | | 573410 | 1254 | 2/3 72 | 72 | 592380 | 1825 | 2/3 72 | 72 | 620756 |
| 0924 | B 2/3 | 84 | 573450 | 1300 | Counter | | 592800 | 1830 | 2/3 74 | 74 | 621042 |
| 0924 | B II | 124 | 573480 | 1400 | Counter | | 597120 | 1833 | 2/3 76 | 76 | 621284 |
| 0924 | B 2/3 | 84 | 573580 | 1427 | 2/3 74 | 74 | 599060 | 1842 | 2/3 74 | 74 | 621983 |
| 0924 | B 1/3 | 44 | 573590 | 1500 | Counter | | 601540 | 1900 | Hour | | 623310 |
| 0925 | 2 | | 573630 | 1526 | 2/3 72 | 72 | 603460 | ~~1903~~ | ~~2/3 70~~ | RPM | ~~623354~~ |
| 0930 | B II | 124 | 573640 | G. J. Parron Lt. (jg) | | | | 1903 | 2/3 71 | 71 | 623511 |
| 0932 | 2 | | 573890 | 1600 | Counter | | 605870 | 1911 | 2/3 73 | 73 | 624173 |
| 0936 | B II | 124 | 573970 | H. P. Steffan MMC | | | | Carlson J. C. MMC | | | |
| 0937 | 2 | | 574030 | 1656 | II 164 | 164 | 609723 | R. P. Metzger Ens USN | | | |
| 0940 | 1/3 | 37 | 574070 | 1700 | Hour | | 610350 | | | | |
| 0949 | 2/3 | 74 | 574340 | 1704 | II 168 | 168 | 610976 | 1954 | 2/3 71 | 71 | 627240 |
| 1000 | Counter | | 575180 | 1710 | II 166 | 166 | 611930 | 2000 | Counter | | 627680 |
| 1009 | I | 110 | 515820 | 1712 | II 162 | 162 | 612319 | 2003 | 2/3 72 | 72 | 627900 |
| 1100 | Counter | | 581580 | 1734 | II 158 | 158 | 615817 | 2009 | 2/3 74 | 74 | 628329 |
| 1129 | 2/3 | 74 | 584840 | 1736 | II 161 | 161 | 616074 | 2015 | 2/3 72 | 72 | 628757 |

Figure 18–7.—Engineer's Bell Book, page 1.

ENGINEER'S BELL BOOK—Continued

| (1) TIME | (2) SIGNAL | (3) R. P. M. | (4) COUNTER | (1) TIME | (2) SIGNAL | (3) R. P. M. | (4) COUNTER | (1) TIME | (2) SIGNAL | (3) R. P. M. | (4) COUNTER |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2029 | 2/3 74 | 74 | 629769 | | | | | | | | |
| 2100 | Counter | | 632080 | | | | | | | | |
| 2103 | 2/3 72 | 72 | 632330 | | | | | | | | |
| 2109 | 2/3 70 | 70 | 632719 | | | | | | | | |
| 2138 | 2/3 72 | 72 | 634819 | | | | | | | | |
| 2158 | 2/3 74 | 74 | 636260 | | | | | | | | |
| 2200 | Counter | | 636380 | | | | | | | | |
| 2208 | 2/3 72 | 72 | 63[illegible]9 | | | | | | | | |
| 2228 | 2/3 74 | 74 | 638441 | | | | | | | | |
| 2242 | 2/3 72 | 72 | 639418 | | | | | | | | |
| 2300 | Counter | | 640760 | | | | | | | | |
| 2336 | 2/3 74 | 74 | 643389 | | | | | | | | |
| AUSAVICH. H MMC | | | | | | | | | | | |
| R.C. Freeman, Ch Mach | | | | | | | | | | | |
| D.E. Cole, Ch. Elec. | | | | | | | | | | | |
| 2344 | 2/3 76 | 76 | 643930 | | | | | | | | |
| 2356 | 2/3 73 | 73 | 644880 | | | | | | | | |
| 2400 | Counter | | 645160 | | | | | | | | |
| W.E. Hare, ENC | | | | | | | | | | | |
| D.E. Cole, Ch. Elec | | | | | | | | | | | |
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INSTRUCTIONS

A single sheet shall be used for all shafts each date except where the control or throttle station arrangements make it impracticable, in which case entries shall be made on the requisite number of separate sheets.

In column 1, times shall be entered according to the system described in U. S. N. R. 1920, Art. 1032(3).

In column 2 the following abbreviations shall be used for recording the meaning of each "bell," signal or order (shaft designating letters to be entered when sheet is used for more than one shaft): S=starboard engines, P=port engines, C=center engines, B=back, Z=zero speed or stop, 1/3=one-third, 2/3=two-thirds, I=standard, II=full, and III=flank speed. There is no abbreviation for "All engines," or "ahead." Omission of any reference to which engines means "All engines." Omissions of any reference to direction means "ahead." Examples: B2/3=all engines back two-thirds speed; 2/3=all engines ahead two-thirds speed; S2/3=starboard engines ahead two-thirds speed. If a definite number of propeller R. P. M. is ordered, then that number shall be entered. Examples: 116=all engines ahead 116 R. P. M.; P75=port engines ahead 75 R. P. M.

In column 3 shall be entered the number of the propeller R. P. M. resulting from action taken. Omission of reference to engines used or direction indicates that those items correspond to the order as recorded in column 2.

In column 4 enter the counter reading at the time the change is made. Also enter the counter reading each hour on the hour.

Before going off duty the engineer officer of the watch shall sign this record in the line following his watch and the next officer shall continue the record immediately after.

Alterations or erasures are not permitted. Necessary corrections shall be made by a note written across blank lines of the record.

U. S. GOVERNMENT PRINTING OFFICE 16—[illegible]-1

Figure 18–8.—Engineer's Bell Book, page 2.

from the action taken (column 3); and the counter reading at the time the order is given (column 4).

Note that the rpm entry in column 3, for any signal, indicates the rpm "resulting from the action taken"—not necessarily the rpm which has been ordered. Sometimes the signals are given in such rapid succession that there is not time

to reach the rpm for one signal before the next signal is received. In such cases, record the rpm that is being made at the time the next signal is given. A counter reading is taken every hour on the hour.

For each day a new sheet is started. The original entries must remain without erasures. Errors must be overlined, initialed, and corrected by putting the proper entry in the space below. Entries are normally made by the throttleman, except when entering or leaving port, or during any rapid maneuvering activity, at which time the entries may be made by an assistant in order that the throttleman can devote his full attention to answering bells. At the end of a watch the throttleman signs his name after the last entry. By 0830 of each day, the record of the preceding day is turned in to the log room.

The Engineer's Bell Book should be kept at each throttle station. Entries should be made in accordance with the instructions on the form, and as outlined in *Navy Regulations*.

Before accepting relief, the engineer officer or the MMC, or other PO in charge of the station at which the throttle is located, should sign this record in the line below that of the throttleman's signature. The record should be continued in the line following the signatures.

## OPERATING RECORDS

A constant check of all machinery and units in operation must be made by the men on watch in the machinery spaces. The data obtained by the watch standers are entered on records referred to as operating logs.

The information contained in the logs provides a basis for the analysis of machinery performance. Therefore, it is the responsibility of all watch standers, particularly petty officers in charge of the watch, to ensure that the information is regularly and accurately given.

Operating records should be completely and accurately filled out by personnel in each machinery space. The man designated to record readings should be carefully instructed

in the manner in which this should be done, and the necessity for reporting immediately any variation from the normal reading noted. It is the responsibility of the petty officer in charge of each space to personally check the reading recorded and to report any unusual condition to the engineer officer, or to the CPO of the watch. No part of the foregoing should be construed as relieving the petty officer, in charge of the space, of the responsibility of personally checking all gages and thermometers; he should supplement the visual check by the use of ears and hands, at intervals of frequency sufficient to ensure proper operation of the plant at all times.

## NIGHT STEAMING ORDERS

In addition to the engineering department's standing orders, the engineer officer, each night the ship is under way, prepares an Engineer Officer's Night Order Book for the benefit of the officer, or CPO, of the watch. These orders, or instructions, become effective as soon as they are received. The forms used will vary from ship to ship, but the content will be similar. The officer of each night watch should initial the orders.

The orders usually indicate the standard speed in knots and rpm; boilers to be used; steam temperature; operating, standby, and emergency fuel oil tanks to be used; make-up, standby, and emergency feed water tanks; and such special instructions as may be necessary (e. g., shifting of ship's service generators, changing of boilers and plant for major speed changes, blowing of tubes, etc.). Figure 18–9 illustrates an example of the Engineer Officer's Night Order Book.

## LIGHTING-OFF AND SECURING CHECK-OFF SHEETS

The Lighting-Off Check-Off Sheet, shown in figure 18–10, and the Securing Check-Off Sheet, shown in figure 18–11, vary from ship to ship, depending upon the procedure de-

ENGINEERING DEPARTMENT
NIGHT STEAMING ORDERS

19 April 19 53

ANCHORED
MOORED Norfolk, Va. TO Lisbon, Portugal
ENROUTE

SPLIT PLANT OR CROSS-CONNECTED
Split plant

S/S 15 KNOTS 85 RPM

STEAM PRESSURE 600# SUPERHEAT TEMP. 850°F SPRAYER PLATES 3712

| | |
|---|---|
| BOILERS 1, 2, 3, & 4 A | STANDBY 1, 2, & 3 Baker<br>4 Charlie |
| TURBOGENERATORS<br>1 A & B; 3 A & B | STANDBY 2A & B; 4A & B |
| EVAPORATORS<br>1, 2, 3, and 4 | DISTILLING TO: Ship's tanks |
| FIRE & FLUSHING PUMPS<br>6, 9, and 10 | STANDBY 4 and 7 |

1. Blow tubes and pump bilges once each watch with permission of O O D.
2. Conduct simulated casualty control drills in all steaming spaces.
3. Keep security patrols alert for fire and/or flooding hazards.
4. The ship expects to fuel destroyers at 0700. See that personnel concerned are notified.

M. C. Andrews

M. C. ANDREWS — NAME | CDR USN — RANK

| | |
|---|---|
| 20-24 | J. A. T. |
| 00-04 | M. S. |
| 04-08 | J. O.B. |

Figure 18–9.—Engineer Officer's Night Order Book.

veloped by the type commander. You should become familiar with the type of check-off sheets used on your ship.

The purpose of the check-off sheet is to provide a reference list or guide to assist the MM1 or C in charge of lighting off or securing an engineroom. Although experienced Machinist's Mates are capable of lighting off and securing enginerooms, there are times when the most experienced person will overlook an important step in the procedure.

PROCEDURE FOR LIGHTING OFF MAIN ENGINES

℄ Engine Room Underway At 0900 Date 9/3/45

| No. | | Actual time | Time All'd | Initial |
|---|---|---|---|---|
| 1. | Call Steaming Watch.................... | 0645 | 2:15 | N.A.P. |
| 2. | Set Steaming Watch in the FR's & ER's.. | 0700 | 2:00 | W.O.L. |
| 3. | Open and close all throttle valves Slack off on stern tube glands.......... | 0715 | 1:45 | W.O.L. |
| 4. | O.O.W. order fires lighted under boilers " 1 , 3 and 4 . | 0715 | 1:45 | W.O.L. |
| 5. | Drain all main and auxiliary steam lines.................................. | 0715 | 1:45 | W.O.L. |
| 6. | Line up main and auxiliary steam lines auxiliary exhaust, drain, & feed lines. | 0718 | 1:45 | W.O.L. |
| 7. | Check location of Turbine rotors, Log Cold Reading............................ | 0718 | 1:45 | W.O.L. |
| 8. | Open drains from throttles, main steam, auxiliary steam and turbines. Leave slightly cracked until steam is coming out of drains freely. Then shift to HP Dr. System................. | 0720 | 1:40 | W.O.L. |
| 9. | Check L.O. Sumps for level and Water. Clean strainer.......................... | 0722 | | W.O.L. |
| 10. | Start warming up main and auxiliary stem. Lines, using by-pass valves where fitted. Otherwise crack valves.. | 0730 | 1:30 | W.O.L. |
| 37. | Check location of turbine rotors Log (hot) readings.......................... | 0830 | 0:30 | W.O.L. |
| 38. | Obtain permission from O.O.D. (personally) to test main engines, if granted disconnect jacking gear. Spin engines every 3 min. while standing by. (Not over 5 turns in any direction). Cut in: 1st. stage Air Ejector and bring up vacuum. Split Plant.................. | 0830 | 0:30 | W.O.L. |
| 39. | When in all respects ready to get underway, report same to Engineer Officer..... ........................ | 0840 | 0:20 | W.O.L. |
| 40. | Close turbine drains on first bell except for last stage drain............ | 0858 | | W.O.L. |
| 41. | Underway................................ | 0900 | 0:00 | |

BE SURE ORDERS TO STAND-BY TO ANSWER ALL BELLS COMES FROM O.O.D.

A. L. Wetzel
(C.P.O. In Charge)

**Figure 18–10.—Lighting-Off Check-Off Sheet (differs for each ship).**

The form will simplify matters and provide a convenient method of checking off the various steps in the procedure. In that way, no steps will be overlooked. The check-off list is filled out by the MM1 or C when he is supervising the men in lighting off or securing an engineroom.

U.S.S. ROCHESTER

ENGINE ROOM SECURING SHEET

#________Engine Room                                                                 Date________

| No. | Operation | Time | Check | Actual Time |
|---|---|---|---|---|
| 1 | Open up 600# Aux. steam line fwd. & Aft., leave main steam split | As Ordered | | |
| 2 | Open up 150# steam line fwd. & aft. | " " | | |
| 3 | Open up Aux. Exhaust lines | " " | | |
| 4 | Open Main Engine drains | On Orders | | |
| 5 | Close Guarding Valves | At Secure | | |
| 6 | Engage jacking gear and start jacking Main Engines (Continue for $1\frac{1}{2}$ hrs | "/ | | |
| 7 | Shift from steam to electric condensate Pumps. | When Ordered | | |
| 8 | Shift from steam to electric Feed Booster Pumps. | " " | | |
| 9 | If practicable, shift from Steam to Electric Fire Pumps | " " | | |
| 10 | Secure designated boiler and Gen s | " " | | |
| 11 | Secure unused sections of Main Steam Line | " " | | |
| 12 | Secure Anchor and Steering Engines; Whistle and Siren. | " " | | |
| 13 | Cut Aux. Exh. into Aux. Condenser and start taking on make-up feed through Aux. Condensers. | " " | | |
| 14 | Drain down unused sections of Steam Lines. | " " | | |
| 15 | Secure dumping valves, gland sealing steam, air ejectors and condensate pumps on 3 main units. Keep all main circulators in operation. | " " | | |
| 16 | Secure Aux. Exh. to D.F.T. not in use | " " | | |
| 17 | Secure remaining Main Condensers when Aux. Exh. pressure becomes normal. | " " | | |
| 18 | Secure Main Circulators when trunk temperature is below 100°F. | When Cond are cooled to 90° | | |
| 19 | Secure all unnecessary sections of Steam lines and drain. | As Ordered | | |
| 20 | Secure jacking gear and main lube oil pumps when Exh. trunk temp. reaches 90°. | Not less than 1 hr after engaging jack gear | | |
| 21 | Set Auxildary Watch. | On Orders | | |
| 22 | O.O.W. report to O.O.D. that Main Engines are secured and what boilers and Generators are being used for Auxiliaries Purposes. | When Ordered | | |
| 23 | O.O.W. report to Engineer Officer that Main Engines are secured. | At Secure | | |

____________________
(C.P.O. in charge)

Figure 18–11.—Securing Check-Off Sheet (differs for each ship).

In addition to the Material History and CSMP Cards, the engineering maintenance records with which you will be concerned include such items as the different periodic check-off lists, work books, zinc charts, and packing lists.

Check-off lists are used to ensure that no item of equipment is overlooked in carrying out the ship's preventive maintenance program.

The check-off sheets comprise numerous daily, weekly, monthly, quarterly, and other tests and inspections. These checks should be accomplished to ensure that the engineering plants and auxiliary equipment are always kept in first-rate operating condition. The type commander usually provides the check-off lists that your ship should use when conducting tests and inspections.

For most steam-driven ships, some items will vary according to the type of ship. Therefore, the following check-off lists will not be complete lists that are applicable to all ships. The object is to give you, as an MM1 or C, an idea of the purpose and scope of the various routine check-off lists. For particular details you should review the check-off lists used on board your ship.

### Daily Check-Off Lists

The following tests and/or inspections should be performed daily:

1. Jack over the main turbines 1¼ turns, with the lube-oil pumps running.
2. Turn all idle auxiliary turbines by hand, and circulate oil by means of a hand pump.
3. Run the main air ejector for ½ hour.
4. Inspect the parts under vacuum for leaks (when steaming).
5. Test the evaporator coil and shell relief valves manually.
6. Jack over the high-pressure air compressors manually.
7. Jack over all pumps by hand.

8. Drain water from the lube oil in the drain tank, to prevent water from mixing with the lubricating oil.

9. Test the lube oil in the reduction gears for purity, and run impure oil through the purifier.

10. Vent the water sides of refrigeration and air-conditioning condensers.

11. Check accessible refrigeration and air-conditioning system parts for proper operation, and check the entire system for unusual noise or vibration. (A separate check-off sheet lists each refrigerated or air-conditioned space.)

The check-off list should be carefully followed and turned

USS Ingersoll (DD652)
DAILY TESTS AND INSPECTIONS

Week Ending March 17, 1954 M DIVISION

| Test or Inspection | Day Test Made (Initials) Sun. | Mon. | Tues. | Wed. | Thur. | Fri. | Sat. | Remarks |
|---|---|---|---|---|---|---|---|---|
| 1. Test parts under vacuum (when steaming) | FWA | FWA | FWA | FWA | FWA | FWA | FWA | |
| 2. Jack turbines 1¼ turns | HER | HER | HER | HER | HER | HER | HER | TURBINES NOT JACKED - TUES. DIVERS OVER THE SIDE |
| 3. Circulate lubricating oil in system | JDE | JBS | JDE | JBS | JDE | JDE | JDE | |
| 4. JACK idle turbogenerator by hand and circulate oil by hand pump | ERH | ERH | ERH | ERH | ERH | ERH | ERH | |
| 5. TURN OVER reciprocating machinery by steam or power | TWS | TWS | TWS | TWS | TWS | TWS | TWS | |
| 6. JACK idle pumps by hand | PM | PM | PM | PM | PM | PM | PM | |
| 7. Run main and auxiliary air ejectors ½ hour | JB | JB | JB | JB | JB | JB | JB | |
| 8. Test evaporator shell relief valves manually | SmH | SmH | SmH | SmH | SmH | SmH | SmH | |
| 9. Inspect piping system | SA | SA | SA | SA | SA | SA | SA | |
| 10. Drain water from lube oil settling tank | JEC | JEC | JEC | JEC | JEC | JEC | JEC | |

NOTE: Later forms: Refer to BuShips Manual instructions for each item.

Figure 18–12.—Daily check-off list (differs for each ship).

into the log room after the tests and inspections have been completed. Figure 18–12 illustrates a form of daily check-off list.

## Weekly Check-Off Lists

Equally important are the weekly tests and inspections. The check-off procedure is similar to that used in the daily check-off lists. Included in this weekly check are the following items:

U.S.S. LEYTE (CV-32)

Week Ending April 8th 1949

WEEKLY INSPECTION, CHECK OFF LIST FOR SHIP'S SERVICE EQUIPMENT

| EQUIPMENT | LOCATION | DATE. | CHECKED BY | REMARKS |
|---|---|---|---|---|
| DISHWASHER #1 | WARDROOM PANTRY | 4/8/49 | Vogel | good |
| DISHWASHER #2 | CREW'S SCULLERY | 4/8/49 | Vogel | good |
| DISHWASHER #3 | CREW'S SCULLERY | 4/8/49 | Vogel | good |
| DISHWASHER #4 | CPO'S MESS | 4/8/49 | Vogel | good |
| FOOD CUTTER | VEGETABLE ROOM | 4/8/49 | Dickerson | good |
| MEAT SLICER | BUTCHER SHOP | 4/8/49 | Albertson | good |
| BONE SAW | BUTCHER SHOP | 4/8/49 | Albertson | good |
| PEELER #1 | VEGETABLE ROOM | 4/8/49 | Albertson | good |
| PEELER #2 | VEGETABLE ROOM | 4/8/49 | Dickerson | good |
| KITCHEN CAKE MACHINE #1 | W.R. PANTRY | 4/8/49 | Albertson | good |
| KITCHEN CAKE MACHINE #2 | BAKERY | 4/8/49 | Albertson | good |
| KITCHEN CAKE MACHINE #3 | CREW'S GALLEY | 4/8/49 | Albertson | good |
| KITCHEN CAKE MACHINE #4 | OFFICERS GALLEY | 4/8/49 | Vogel | good |
| BREAD SLICER | BREAD ROOM | 4/8/49 | Dickerson | good |
| LAUNDRY FLAT WORK IRONER | LAUNDRY | 4/8/49 | Albertson | good |
| LAUNDRY DRYER TUMBLER #1 | LAUNDRY | 4/8/49 | A Albertson | good |
| LAUNDRY DRYER TUMBLER #2 | LAUNDRY | 4/8/49 | A Albertson | good |
| EXTRACTOR #1 | LAUNDRY | 4/8/49 | A Albertson | good |
| EXTRACTOR #2 | LAUNDRY | 4/8/49 | A Albertson | good |
| EXTRACTOR #3 | LAUNDRY | 4/8/49 | A Albertson | good |
| WASHER #1 out of Commission | LAUNDRY | 4/8/49 | out of commission | |
| WASHER #2 | LAUNDRY | 4/8/49 | Albertson | good |
| FORMITE COLLAR IRONER AND SHAPER | LAUNDRY | 4/8/49 | Albertson | good |
| GARMENT PRESS #1 | MARINE SHOP | 4/8/49 | A Albertson | good |
| GARMENT PRESS #2 | TAILOR SHOP | 4/8/49 | A Albertson | good |
| GARMENT PRESS #3 | TAILOR SHOP | 4/8/49 | A Albertson | good |
| GARMENT PRESS #4 | LAUNDRY | 4/8/49 | A Albertson | good |
| GARMENT PRESS #5 | LAUNDRY | 4/8/49 | A Albertson | good |
| GARMENT PRESS #6 | LAUNDRY | 4/8/49 | A Albertson | good |
| GARMENT PRESS #7 out of Commission | LAUNDRY | 4/8/49 | A Albertson | good |
| GARMENT PRESS #8 | LAUNDRY | 4/8/49 | A Albertson | good |
| GARMENT PRESS #9 | LAUNDRY | 4/8/49 | A Albertson | good |
| GARMENT PRESS #10 | LAUNDRY | 4/8/49 | A Albertson | good |
| GARBAGE GRINDER #1 | DISPOSAL ROOM | 4/8/49 | A Albertson | good |
| GARBAGE GRINDER #2 | DISPOSAL ROOM | 4/8/49 | A Albertson | good |
| STENCILING MACHINE #1 | LAUNDRY | 4/8/49 | A Albertson | good |
| STENCILING MACHINE #2 | LAUNDRY | 4/8/49 | A Albertson | good |
| MEAT GRINDER | BUTCHER SHOP | 4/8/49 | A Albertson | good |
| SEWING MACHINE | TAILOR SHOP | Taken care of by themselves | | |
| STICHER | COBBLER SHOP | Taken care of by themselves | | |
| STITCHER | COBBLER SHOP | Taken care of by themselves | | |
| SEWING MACHINE | COBBLER SHOP | Taken care of by themselves | | |
| SEWING MACHINE | SALE LOCKER | Taken care of by themselves | | |
| SEWING MACHINE | PARACHUTE SHOP | Taken care of by themselves | | |

NAME Frank De Salvo WMl/c

Figure 18–13.—Typical weekly check-off list for miscellaneous auxiliary machinery.

1. Check all valves, fittings, and joints of steam, exhaust, and drain lines for tightness.

2. Operate manually the relief valves on all piping systems in your assigned spaces.

3. Operate all pumps by steam or motor power.

4. Lubricate all emergency control governors, and trip the emergency governors by hand.

5. Operate and lubricate all operating gear where necessary, and propulsion plant valves not in use.

6. Operate all air compressors by power.

7. Test refrigerating and air-conditioning systems for possible refrigerant leaks.

8. Operate all idle refrigerant compressors by power, and alternate the compressors.

9. Clean all sea water strainers, where blowout line connections are provided.

10. Operate and lubricate all valves, to prevent sticking.

You can readily see how easy it would be to forget an item on your ship if you attempted to inspect the equipment and conduct tests without using a check-off list. The weekly check-off list illustrated in figure 18–13 applies to the ship's service equipment of the "A" (auxiliary) division. If you are assigned to that division, you will be able to use such lists to guide you in making periodic inspections and tests. Other sheets may apply only to the ship's heating system, or to the refrigeration system, or to the air-conditioning system. Additional check-off lists of this nature may be maintained by the engineering department of the ship, as prescribed by the engineer officer.

### Monthly Check-Off Lists

Some items of equipment, mechanisms, and systems do not require daily or weekly checks but they should be tested and inspected at least once a month. The following items should be included in this monthly check:

1. Inspect the reduction gears, the exhaust trunk, and the main turbines through the inspection plates.

2. Inspect the lube-oil sump tanks.

3. Purify all lube oil.

4. Inspect and clean, or renew, all zincs installed in the engineering equipment.

5. Test all valves not in frequent use, and test remote-operating gear to all valves.

6. Renew the shaft packing of all rotary pumps bimonthly.

7. Inspect and clean the air filters and the intake valves to all air compressors.

8. Test the overspeed and back pressure trips and the relief valve settings on all turbogenerators.

### Quarterly Check-Off Lists

As required by BuShips, a more complete test and inspection of certain items of equipment is conducted quarterly. The following items are included in these lists:

1. Inspect the exhaust trunk and the last few stages of the low-pressure turbine through the manhole plate to detect corrosion or other defects.

2. Sound all turbine holding-down bolts, ties, and chocks with hammer to detect signs of loosening.

3. Clean the steam strainers to prevent foreign matter from entering turbines, and to ensure strainer integrity.

4. Remove the turbine inspection plates to determine the existence of loose blades or shrouding, or the presence of corrosion.

5. Check the thrust bearing shoe clearance, the condition of the bearing surface, and the position of the turbine rotor.

6. Blow out the thrust with air after examination to prevent foreign matter from remaining therein.

7. Inspect for correct radial clearance by checking the main bearings for clearance, and checking the condition of the journal and the bearing surface.

8. Inspect the exhaust trunks for tightness, evidence of corrosion and loose bolts.

9. Inspect the gland packing for wear to ensure that an efficient seal is maintained.

10. Remove the reduction gear inspection plates, and inspect the gears and the oil-spray nozzles to ensure that they are free of scale and that an even oil flow is maintained. (Gear should be jacked for one-half hour with lube oil at operating pressure.)

11. Overhaul all auxiliary throttle valves.

12. Test all engineering piping to full pressure.

13. Inspect the water sides of the main and auxiliary steam condensers to determine if cleaning is necessary.

14. Test and calibrate all gages.

15. Inspect all reducing valves; if necessary, overhaul.

16. Make a general inspection of air compressors, including the testing of gages, valves, bearings, filters, intercoolers, air passages, cylinders, speed-limiting governors, overspeed trips, and the electric load required for starting.

17. Check the relief valve settings on all reciprocating pumps, and check the steam valve gear for wear; inspect the liquid end valves (stems, disks, seats, springs, etc.).

18. Check all centrifugal and rotary pumps by testing the overspeed and speed-limiting devices and all relief valves, by cleaning the lubrication system, by renewing the lube oil or grease, by checking all foundation bolts and dowel pins, and by checking the internal water-cooled bearings and shafting.

### Other Periodic Check-Off Lists

In addition to the daily, weekly, monthly, and quarterly reports, the type commander may also require the maintenance of semiannual and annual check-off lists. Aboard ship, the engineer officer may, from time to time, direct the preparation and maintenance of check-off lists that will include such items throughout the engineering spaces as it is deemed necessary to inspect and/or test.

### Under Way Check-Off Lists

An under way check-off sheet is usually required by the type commander to ensure that certain tests or checks are made in the enginerooms when a ship is under way. References to related articles of information or instruction in

BuShips *Manual* may accompany most of the items listed. Space is provided for the items to be checked on each watch. Typical listings on these sheets are as follows:

1. Inspect the stern tube glands frequently for the proper flow (leakage) of cooling and lubricating water.

2. Follow posted instructions before putting the lube oil system into use.

3. While under way, test the main condenser for salinity every 15 minutes and the auxiliary condenser every 30 minutes. (Salinity should not exceed 0.1 epm.)

4. Test the deaerating feed tank for chloride once each watch. (Chloride concentration should not exceed 0.15 epm and must not exceed 0.5 epm.)

5. Test the fuel oil heater drains and the tank heating coils, when in use, hourly for any traces of oil.

6. Inspect the lube oil flow through the sight glass frequently.

7. Clean and inspect the lube oil strainers before getting under way, and during each watch.

8. Inspect and test the float gage on the lube oil sumps frequently.

9. Log the amount of oil in the sump drain tank at the end of each watch.

10. Test the water side of the oil cooler for any trace of oil, once each watch.

11. Frequently inspect the bearings, oil lines, etc., for oil leaks; and inspect the bilges for the presence of oil.

12. Operate the oil purifier each day until any trace of water is eliminated.

13. Make routine inspections of the operating conditions of the main shaft bearing.

14. Test or inspect the oil in all self-oiling bearings, after 10 days of intermittent service.

15. Note the position of the finger pieces and the telltale indicators of each turbine frequently during each watch.

16. Take cold and hot dummy clearances before getting under way and take a clearance once each watch.

17. Read all gages and thermometers frequently during each watch.

18. Clean the bilge suction strainers during each watch.

19. Listen for any possible defects in the ball thrusts, and in the radial bearings, during each watch.

20. Inspect the bearings for abnormal temperatures, or overheating; this inspection should be made frequently during each watch.

## Rough Machinery History Books

Each major engineering machinery space aboard ship maintains a Rough Machinery History Book for machinery installed in the space. The purpose of these machinery history books is to keep a detailed record of all tests, maintenance, alterations, and repairs made to each unit of machinery under the cognizance of the Machinist's Mates in the space. You will be responsible for seeing that these books are made up and maintained in accordance with current directives. All books are usually turned into the log room, prior to 1000 every Friday. The engineer officer, or his representative, inspects all entries made during the week, noting applicable items for entry on the Machinery History Cards, and initials the last entry. The log room Yeoman transfers the indicated entries to the smooth record cards, initials the items entered, and returns the books to the respective spaces.

The work books can be in ledger or loose-leaf notebook form. A suitable index listing the equipment and its machinery index number, together with the page or tab number in the Rough Machinery History Book on which it will be found, should be prepared at the front of the book.

Separate pages, or groups of pages, of the Rough Machinery History Book are devoted to individual units of machinery. At the beginning of the first page for each unit there should be entered such identifying and name-plate data as the index number, which is the same as the Machinery History Card; a description of the unit (name, manufacturer, type, size, serial number); the location (space, compartment,

and frame); applicable BuShips plant number and title proper identification of the manufacturer's instruction book and information regarding repair parts and special tools This information is identical with the data recorded in the ship's Machinery Index, maintained in the log room, and can be copied directly from that record.

Entries in the history should be a record of all repairs made and parts renewed on each piece of machinery, along with the date of repairs and the name of the individual making them. The idea is to make the entries brief, but complete. List only the facts and data which are essential for future knowledge of work done on the machine. Include such maintenance and repair information as: date when oil or zinc was renewed, the amount and type of oil, when packing was renewed, important tests, repair parts used, measurements taken, and other technical data.

## Zinc Check-Off Charts

Because of the importance of zinc pieces in the prevention of galvanic action in the ship's machinery, zinc inspection and renewal check-off charts (shown in fig. 18–14) are prepared for most ships. Ships that are not furnished charts should make up their own charts. With the use of these charts, supervisor personnel can be fairly certain that all zincs are included in the maintenance program. The zincs must be inspected and cleaned monthly, more often if they become coated or disintegrate rapidly. If the zinc plates or pencils weight only 50 percent of their original weight, after cleaning, they should be replaced.

This chart lists each zinc piece installed in the ship's air compressor plant, distilling plant, main and auxiliary condensers, and other heat exchangers, and various pumps used in salt-water systems. Information given for each zinc includes the machinery location, machinery name, zinc location in the machinery, number of zinc pieces at the location, type of zinc pieces installed, dates of inspection, and whether zincs were renewed at the inspection.

The types of zincs installed are listed and described on the right-hand side of the chart. The standard shapes (pencil, disk, and rectangular plate) are listed according to the various specifications. Other shapes and sizes peculiar to a ship are sketched and described in the spaces provided.

A supply of zinc pencils and plates is maintained on board ship. Zinc pencils, and in many cases zinc plates, are manufactured from rod and plate stock by the ship's machine shop personnel. A zinc chart, or other form of detailed data, must be kept on hand by the person in charge of the machine shop, so that the shop can produce a reserve supply of the various types of zincs.

### Packing Charts

Each vessel should have a chart (or charts) showing the packing required for each piece of machinery, hull fittings, and piping system, listing thereon the appropriate symbol number, the amount, and the size of the packing. A packing chart which gives detailed instructions in regard to packing material and gaskets should be posted in each engineroom or engineering space. This chart should be prepared from the plan material lists (blueprints), manufacturers' instructions, and applicable chapters of BuShips *Manual*. Navy symbol numbers should be used whenever possible. To simplify the preparation of requisitions and to ensure that proper stocks are maintained, the packing charts should also include quantities installed and stock catalogue numbers. It is the responsibility of an MM1 or C to check packing and gaskets being installed, to ensure that proper material and procedures are being used for each type of job.

## MISCELLANEOUS RECORDS AND PUBLICATIONS

In addition to the records discussed up to this point, there are several other miscellaneous records and publications with which you, as an MM1 or C, may be concerned. These include Operating Instructions and Safety Precautions, Work Request Memoranda, BuShips *Manual*, BuShips *Journal*, and manufacturers' instruction books.

## Operating Instructions and Safety Precautions

A master list of all the engineering department posted operating instructions and safety precautions is kept on file in the log room. When a new ship has been built, the building yard normally provides a master copy in addition to posting the individual operating instructions and safety precautions throughout the engineering spaces. In case any of the posted operating instructions and safety precautions are damaged or lost, a duplicate copy can be readily made up from the master list. Plastic sheets are provided on many ships for the posted operating instructions and safety precautions. Depending upon the type of ship that you are on, these plastic posters usually can be made up or requisitioned.

In cases where operating instructions and safety precautions are not provided, they should be made up by the ship's force. The required instructions can be obtained from the manufacturers' instruction books and the applicable chapters in BuShips *Manual*.

## Work Request Memoranda

An interdepartment routine request for work requiring assistance by another shipboard department is referred to as a ship's memorandum work request. Such a form enforces proper channeling of a work request between departments, and permits the setting up of priorities of available manpower and facilities. The work request memoranda is a form which is made up by the ship; however, some ships use the Repair Record Card, or the repair work request for this purpose.

## BuShips *Manual*

BuShips *Manual* is issued for the information and guidance of naval personnel. Administrative and technical instructions which are not included in *Navy Regulations*, but which are deemed necessary for a clear understanding of the requirements of the work under the cognizance of BuShips, are given in this publication. The data and instruc-

tions pertaining to the machinery installations of Navy ships are, to some extent, general in nature. BuShips *Manual* instructions are in accordance with what is considered the best engineering practice for the operation, maintenance, and repairs of machinery and equipment. In order to clarify the instructions, brief descriptions of type units, or plants, have been included. For complete information on details of design, blueprints or drawings should be consulted. For details of description, operation, adjustment, and care of machinery, the manufacturers' instruction books should be studied.

A bound copy, and usually individual chapters, of BuShips *Manual* are maintained on file in the log room. As an MM1 or C, you should be familiar with the various chapters that pertain to your rating. You may obtain copies of individual chapters from the Superintendent of Documents, Government Printing Office, Washington, D. C.

### BuShips *Journal*

The BuShips *Journal* is a relatively new publication, appearing monthly. This journal replaces other previous publications such as *BuShips Bulletin of Information*, *Industrial Notes*, and *Shop Notes*. A number of the articles in the BuShips *Journal* deal with engineering operations, maintenance, and repairs. As an MM1 or C, you should make a practice of reading those articles in BuShips *Journal* that are applicable to your rate. If not otherwise provided, this publication can be obtained from the log room Yeoman.

### Manufacturers' Instruction Books

These instruction books are furnished for machinery and equipment on board ship and, in nearly all cases, are prepared by the manufacturer of the individual piece of equipment. Care should be taken to see that instruction books are provided for each unit of machinery and equipment on board ship. A complete file of manufacturers' instruction books is maintained in the log room. Appropriate instruction

books are sometimes maintained in other engineering spaces.

As an MM1 or C, you must have a detailed knowledge of the machinery and equipment which you are responsible for operating, maintaining, and repairing.

## BLUEPRINTS AND PLAN INDEXES

In order to be proficient in all phases of his work, the MM should possess a thorough knowledge of blueprints (photographic prints, blue, white, or any other color, used for copying drawings or plans) and should be familiar with the method used for filing them. Each ship has a certain allowance of blueprints that should be properly filed, inventoried, and kept up to date.

Although all ships use the same system of filing blueprints, according to their assigned code number, each ship will not have the same number of file jackets, with identical subject-matter groups and plan numbers. The number assigned to a blueprint for identification and filing purposes is composed of several groups. For example, in the BuShips plan number CA139–S5101–525802, the group CA139 designates the CLASS of ship to which the plan applies. The next group is S5101, which is the "S" (subject-matter) group or material file number. In this case it is a blueprint on the general arrangement of a boiler front. The group 525802 is the individual plan number. Another example of a plan number is DE51–S4602–1, where DE is the ship class, S4602 is the subject-matter filing number (in this case condensers), and 1 is the individual plan number.

In cases where an alteration has been made, the blueprint will also have an alteration number; for example, in blueprint number CA139–S5103–528155 Alt. 4, the "Alt. 4" is the alteration number. If all the alterations have been completed, the plan with "Alt. 4" is kept on file and the previous ones (Alt. 1, Alt. 2, and Alt. 3) are disposed of. When working from blueprints, care must be taken to see that you have an up-to-date plan and not one that is obsolete. This can be done by checking the "Alt" numbers and date of alteration. If the last alteration has not been completed, the shop concerned will keep two blueprints on file until such times as the alteration has been completed. In this case

the two plans would be CA139–S5103–528155 Alt. 3 and CA139–S5103–528155 Alt. 4.

You may occasionally come upon a blueprint that does not have an S classification; such blueprints pre-date the present classification system, which has been in use only since May 1944. Before that time the plan number for a particular plan would simply read "476719 Alteration 2." When you find a blueprint with one of these old plan numbers, assign the proper S group filing number. In the example above, the plan (476719) would be filed under the S2600, since it is a plan for the a-c controller for the anchor windlass.

You must have an understanding of the S group, or material group, classifications and numbering because these are used in the filing of blueprints. The *Navy Filing Manual* lists the filing numbers and their subject matter; the same system is used for numbering the various chapters in BuShips *Manual*. For example, blueprints for pumps are in the S4700 group, main turbines are S4100, condensers S4600, and boilers S5100.

For shipboard use, the most satisfactory method of filing these blueprints or plans is to fold them and then insert them in manila envelopes. Each envelope should be labeled with the following information written in the upper left corner: S group classification, plan number, alteration number (if any), and plan title.

Each ship is furnished with a list of plans known as the "Ship's Plan Index." Ships may also have a typewritten index of the plans that are carried on board. The use of an index aboard ship is the best method of finding a blueprint. Assume that repairs were being made to a main feed pump, and a blueprint was needed. The proper procedure would be to go to the engineering log room and obtain the Ship's Plan Index. If you know the filing number for pumps, you can immediately turn to the S4700 group. Here you will find the numbers and the titles of the various blueprints listed. From the listed titles, you can usually spot the blueprint you want; the number opposite the title is then noted.

The next step in the procedure is to go to the filing cabinets where the blueprints are stowed. The file drawers are labeled with the S-group numbers, and the numerical plan number sequence of the blueprints which are in the drawer. Pro-

ceed to the file drawers marked S4700 and look for the numerical sequence that your desired blueprint would come under. For example, if the individual plan number of the desired blueprint was 527903 and the file drawer marked "S4700–527807 through 528014" was located, you would know that the desired plan was in this drawer. The individual blueprint is then removed from the manila envelope, which remains in its proper place in the file, and checked to make sure it is the plan that has the required information. So that the whereabouts of plans removed from the files will always be known, plans should be signed for, either on the manila envelope, or on an index card, or in a book kept for that purpose.

## ENGINEERING REPORTS

In addition to maintaining the operating, maintenance, and miscellaneous records, the engineer officer and the petty officers are also responsible for preparing a large number of reports essential to the efficient administration of the engineering department. Reports serve to keep BuShips and naval activities informed of the daily operations.

### Material Analysis Data Report (NAVSHIPS 3621)

The purpose of the Material Analysis Data and Repair Parts Usage Report, shown in figures 18–15 and 18–16, is to indicate the cause and frequency of repairs and the repair parts used. This report should be submitted to BuShips whenever a repair part is used for machinery, equipment, or hull repair. There are two codes used in making out this report: the CAUSE and REMEDY CODES. These codes are included with the pads of forms issued to the ships of the fleet.

On the face of the form is filled in such information as the type, model, serial number, manufacturer's number and contract number of the machinery or equipment. On the reverse side, the name, number, and quantity of repair parts used are identified. However, if the old part was repaired and revised, the action taken is shown by using the code numbers on the buff-colored sheet found in the pad.

All repairs are reported, but only one repair is listed on each sheet. The repair is identified as clearly as possible. The completed report is forwarded promptly to BuShips.

**MATERIAL ANALYSIS DATA**
**AND REPAIR PARTS USAGE**
NAVSHIPS 3821 (REV. 11-48)

***Use back of this form for list of repair parts used***
***Mail direct to Buships—No copies needed***

REPORT—SHIPS—[illegible]

| SHIP NAME | TYPE | SHIP NO. | DATE |
|---|---|---|---|
| U.S.S. Flight | CV | 338 | Apr. 5, 1949 |

| MATERIAL-$\cdot$-GROUP NO. | EQUIPMENT OR SYSTEM NAME |
|---|---|
| S59-1 | Refrigeration Plant |

| COMPONENT NAME | NAVY TYPE OR MODEL NO. | BUSHIPS COMPONENT STOCK NO. |
|---|---|---|
| #1 Compressor | 7H5 EF | 52124-s5901-596762 |

| MANUFACTURER'S NAME | MFGR. TYPE OR MODEL NO. | COMPONENT SERIAL NO. | CONTRACT NO. |
|---|---|---|---|
| Carrier Corp., N.Y., N.Y. | 7H5 EF | N-1000-1 | NXss 28773 |

REPAIRS WERE (Check one ✓ or X): [X] EMERGENCY TO REPAIR BREAKDOWN [ ] ROUTINE DURING NORMAL UPKEEP

REPAIRS MADE BY (Check one ✓ or X): [X] SHIP'S FORCE [ ] YARD FORCE [ ] TENDER FORCE

REMARKS AND RECOMMENDATIONS

#1 compressor placed in use during routine maintenance work on #2. Approximately 16 hours after initial starting, #1 commenced running hot and a pronounced knocking was heard. Unit was immediately secured and subsequent inspection revealed upper crank bearing on connecting rod assembly scored and cotterpin sheared off. Renewed bearing and pin from spare parts. Assembled and tested unit. Running condition normal.

*This form is stocked in the Central Distribution System.*

16—67479-5

Figure 18–15.—Material Analysis Data and Repair Parts Usage, face.

REPAIR PARTS USED—AND PARTS IDENTIFICATION

*The following parts were repaired or replaced during maintenance or repair activity*
*BE SURE OF THE PART IDENTIFICATION—WRITE LEGIBLY—SUBMIT PROMPTLY*

| NAME OF PART | HRS. IN USE | PART IDENTIFICATION (By Stock No., Buships Plan & Pc No., or Mfr.'s Plan & Pc No.) | UNIT | QUANTITY | CODE | |
|---|---|---|---|---|---|---|
| | | | | | CAUSE | REMEDY |
| Conn. rod ass'y.- | | Mfr's. Dwg. No. 3ME 494-3 | | | | |
| upper crank bearing | 1265 | Pc. No. 258 | Ea. | 1 | 56 | 73 |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |

NAVSHIPS [illegible] (REV. 11-48) (BACK) [illegible] U. S. GOVERNMENT PRINTING OFFICE

Figure 18—16.—Material Analysis Data and Repair Parts Usage, back.

## Operating Data Sheet (NAVSHIPS 3624)

The Operating Data Sheet is submitted by all steam-propelled vessels in service or in commission. This report provides BuShips with data to be used in the analysis of ship performance and to afford a basis for design comparison.

ENGINEERING SHEET I
OPNAV FORM-3540-1 (REV. 12-53)

**MONTHLY SUMMARY**

OPNAV REPORT-3540-3

No letter of transmittal required. Submit by 5th of following month.

| U.S.S. | HULL NO. | TO | MONTH OF |
|---|---|---|---|
| SUPLRSPEED | DD000 | CHIEF OF NAVAL OPERATIONS | Aug. 1954 |

| FLEET AND FORCE ASSIGNMENT | ADMINISTRATIVE CONTROL | OPERATIONAL CONTROL |
|---|---|---|
| | DESLANT | COMSIXTHFLEET |

1. SUMMARY OF ACTIVITIES
   - (a) 1-5 Fleet exercises
   - (b) 7-14 Enroute Naples, Italy to Norfolk, Va.
   - (c) 14-31 In port; upkeep

SAMPLE

| 2. DATA SUMMARY (*Give TOTALS for this month. Use nearest whole number - NO DECIMALS.*) | |
|---|---|
| 2.1 NAVIGATIONAL MILES | 4,650 |
| 2.2 ENGINE MILES | 4,800 |
| 2.3 HOURS UNDERWAY* | 300 |
| 2.4 FUEL USED UNDERWAY (*Gallons*) | 159,900 |
| 2.5 HOURS NOT UNDERWAY* | 444 |
| 2.6 FUEL USED NOT UNDERWAY (*Gallons*) | 33,088 |
| 2.7 HOURS IN EXCLUDED STATUS* | 0 |
| 2.8 FUEL USED IN EXCLUDED STATUS (*Gals.*) | 0 |
| 2.9 FUEL USED FOR GALLEY, BOATS, ETC. (DO NOT INCLUDE IN ITEMS 2.4 & 2.6) (*Gals.*) | 310 |
| 2.10 MAIN ENGINE LUBE OIL USED (*Gallons*) | 200 |
| 2.11 POTABLE WATER MADE ON BOARD (*Gallons*) | [illegible] |
| 2.12 POTABLE WATER RECEIVED FROM TENDER, DOCK, OR BARGE (*Gallons*) | 110,000 |
| 2.13 BOILER MAKEUP WATER FOR RESERVE FEED (*Gallons*) | 36,500 |
| 2.14 CUMULATIVE DAYS SINCE LAST UNDOCKED | 256 |

*ITEMS 2.3, 2.5, & 2.7 MUST TOTAL TO HOURS OF MONTH CORRECTED FOR TIME ZONE CHANGES.

| FOR SUBMARINES ONLY | |
|---|---|
| 2.15 HOURS ON SNORKEL | NOT APPLICABLE |
| 2.16 HOURS SUBMERGED ON BATTERIES | NOT APPLICABLE |

| 3. AVERAGES AND FACTORS | |
|---|---|
| 3.1 AVERAGE RPM | 145 |
| 3.2 AVERAGE UNDERWAY FUEL RATE GALLONS/HOURS | 533 |
| 3.3 AVERAGE NOT UNDERWAY FUEL RATE GALLONS/HOURS | 77 |
| 3.4 FUEL OIL - LUBE OIL RATIO | 960 |
| 3.5 PER CAPITA WATER CONSUMPTION GALLONS/MAN/DAY | 23 |
| | |

| 4. PERFORMANCE RATIOS | |
|---|---|
| 4.1 UNDERWAY PERFORMANCE RATIO - THIS MONTH | 480/533 = .901 |
| 4.2 UNDERWAY PERFORMANCE RATIO - THIS FISCAL YEAR | 475/520 = .913 |
| 4.3 NOT UNDERWAY PERFORMANCE RATIO - THIS MONTH | 67/77 = .870 |
| 4.4 NOT UNDERWAY PERFORMANCE RATIO - THIS FISCAL YEAR | 67/74 = .905 |
| 4.5 OVERALL PERFORMANCE RATIO - THIS MONTH | 547/610 = .897 |
| 4.6 OVERALL PERFORMANCE RATIO - THIS FISCAL YEAR | 1084/1188 = .912 |

5. SUPPLEMENTARY INFORMATION

| | SHIPS FORCE | TENDER | REPAIR BASE | SHIPYARD | TOTAL DAYS |
|---|---|---|---|---|---|
| 5.1 DAYS OF ASSIGNED UNINTERRUPTED AVAILABILITIES OR UPKEEP PERIODS THIS MONTH | 12 | 0 | 0 | 0 | 12 |

5.2 PROPELLER DATA (*To be filled in initially and as changes occur*)

| | ONE SHAFT | TWO SHAFTS | | FOUR SHAFTS | |
|---|---|---|---|---|---|
| | | PORT | STARBOARD | INBOARD | OUTBOARD |
| DIAMETER | | | | | |
| PITCH | | | | | |
| NO. BLADES | | | | | |
| TYPES | | | | | |

Figure 18–17.—Monthly Summary Sheet.

If the ship is not under way for the full month, this fact should be noted on the face of the report, but the data required for sections VII, VIII, and IX on the back of the form are recorded.

All columns applicable to the type of vessel should be completely filled in. Where data cannot be taken because of a lack of meters or instruments, an "X" should be inserted opposite the specific entry. Where correct or accurate data cannot be given because the instruments are unreliable, a "U" should be entered opposite the specific item.

This report is submitted monthly by all steam-propelled vessels in commission, or in service. One report of 10 runs is the minimum monthly requirement. Data are to be collected during normal operating practice when all usual services are being provided and can be taken from various fireroom, engineroom, and other logs, either during or after the run. A run will last for 1 hour regardless of the conditions which preceded or followed the particular hour chosen.

### Monthly Summary (OPNAV 3540–1)

The Monthly Summary (OPNAV 3540–1, REV 12–53), a monthly resume of engineering department operations, should be submitted each month by all ships of the active fleet.

A sample of this form is given on page 613. Detailed information in regard to filling out this form is available in the ship's log room.

## DISPOSAL OF ENGINEERING DEPARTMENT RECORDS

Before any engineering department records are destroyed, the Records Disposal Instructions for Vessels of the United States Navy (OPNAV INSTRUCTION 525.1) should be studied. This pamphlet informs vessels of the Operating Forces of the procedures used for records. For each department aboard ship, these instructions list permanent records which must be kept, and temporary records which should be disposed of.

### Engineering Log and Engineer's Bell Book

Both the Engineering Log and the Engineer's Bell Book sheets must be preserved as permanent records on board ship for a 3-year period unless they are requested by a naval court or board, or by the Navy Department. In the latter case, a copy (preferably photostatic) of such sheets, or parts of these records that are sent away from the ship, is certified by the engineer officer as a true copy for the ship's files.

At regular intervals, such as each quarter, the parts of those records that are over 3 years old are destroyed. Should a vessel be placed in inactive status, the current books, less than 3 years old, should be retained. If a vessel is decommissioned for disposal or scrap, the current books are forwarded to the nearest Naval Records Management Center.

### Operating and Performance Records

Operating logs and performance records (check-off lists, work books, packing charts, etc.) should be kept for at least 6 months before being destroyed.

### Material History Cards

Material History Cards may be destroyed when the individual record has become obsolete by virtue of the fact that the material has been replaced or disposed of. New cards are made out for new equipment or machinery that has been installed on board ship.

Data appearing in the "Remarks" space of the Material History Cards should be retained for a period of not less than 5 years; it may then be destroyed at the discretion of the CO. However, if a ship is decommissioned, this information should be retained on board the ship.

### Current Ship's Maintenance Project Cards

After any repair work or alteration is completed, and entries made on the Material History Cards, the CSMP

cards are transferred to a separate "work completed" file, where they should be retained for a period of 2 years before disposal.

### Reports

Any reports and returns forwarded to, and received from BuShips or superior command may be destroyed when 2 years old, if they are no longer required for any other purpose.

After a notation has been made, on the Material History Card, that the machinery or equipment has been completely overhauled, the Material Analysis Data Reports (NAVSHIPS 3621) may be destroyed.

It is important that only those reports which are either required, or serve a specific purpose, be maintained on board ship. However, any report or record which will assist personnel in scheduling work or making repairs, and which will supply personnel with information which is not contained elsewhere in publications or manuals, should be kept on board ship.

## SUMMARY

Since the proper recording of specific operating and maintenance data will be required of you wherever you may be assigned, it is important that you have a working knowledge of what records and reports must be maintained.

As an MM1 or C, you will have additional supervisory duties which require that you have a greater knowledge of engineering records and reports, along with the associated administrative procedures.

In order to be proficient in all phases of your work, you must possess a good knowledge of blueprints and an understanding of the method of filing blueprints in the Navy.

## QUIZ

1. Where does the data for all engineering records and reports originate?
2. What is the Material History?
3. What card is used to record reciprocating pump measurement?

4. What card is used to keep a record of all repairs pending?
5. When an alteration is pending, what should be done with the Alteration Record Card?
6. When should repair requests arrive at the naval shipyards for a routine overhaul period?
7. How should the individual repair work items be listed?
8. Repair requests should be worded so as to provide the repair activity with what information?
9. To whom should work requests for routine repairs, to be accomplished by tenders or repair ships, be submitted?
10. Where is a record of all pending repairs, whether performed by a naval shipyard, or by a repair activity, maintained?
11. In what form are requests for alterations submitted?
12. What are the official legal records maintained by the engineering department of the ship?
13. How should entries that have been made in error on the Engineering Log Sheet be treated?
14. Who is primarily responsible for proper entries in the Engineer's Bell Book?
15. Which routine check-off list requires the inspection of parts under vacuums for leaks when steaming?
16. How often should oil in all self-oiling bearings be inspected or tested?
17. Data entered in the work books (Rough Machinery Histories) are transferred to what cards?
18. How often are the zinc pencils or plates of the ship's machinery inspected and cleaned?
19. What record shows the packing required for each piece of machinery and piping system in a major engineering space?
20. What is done before any original page of the Engineering Log is sent away from the ship to a naval court or board?
21. Where can one find a list of filing numbers, and subject-matter references, for use in locating blueprints?
22. In the blueprint filing system used aboard ship, how is the subject-matter group indicated?
23. What report has been initiated for the purpose of enabling BuShips to determine the extent to which the repair parts have been used by the ships of the fleet?
24. What is the purpose of the Operating Data Sheet?
25. When is it permissible to destroy old Engineering Log and Bell Book Sheets?
26. When is it permissible to destroy old operating records?

CHAPTER 19

# FORMAL INSPECTIONS AND TRIALS

A naval ship must be inspected from time to time to ensure that her operation, administration, and material are maintained at a high standard of readiness for war. The frequency with which the various types of inspections are held is determined by CNO, the fleet commander, and the type commander. As far as the ship is concerned, the type commander usually designates the type of inspection and when it will be held.

A ship is frequently notified some time in advance when an inspection will take place, but preparation for an inspection should not be postponed until the notice of inspection is received. It is a mistake to think that a poorly administered division or department can, by a sudden burst of energy, be prepared to meet the inspector's eagle eye. By using proper procedures, and keeping up to date on such items as repair work, maintenance work, operating procedures, training of personnel, engineering casualty control drills, Material History Cards, CSMP, operating records, and other records and reports, you will always be ready for an inspection.

Your ship may be required to furnish the inspecting party that will make an inspection on another ship. Should this occur, you as an MM1 or C may be assigned the duty as an assistant inspector. Therefore, you should know something about the different types of inspections and how they are conducted.

## ADMINISTRATIVE INSPECTION

Administrative inspections cover administrative methods and procedures normally employed by the ship, and each inspection is divided into two general categories—the general administration of the ship as a whole, and the administration of each department. In this discussion we will consider the engineering department only.

The purpose of the administrative inspection is to determine (1) that the department is being administered in an intelligent, sound, and efficient manner, and (2) that the organizational and administrative methods and procedures are directed toward the objective of every naval ship—namely, being prepared to carry out her intended mission.

### Inspecting Party

It is a routine procedure for one ship to conduct an inspection on another ship within the division. General instructions for conducting the inspection are usually given by the division commander; however, the selecting and organizing of the inspecting party is done aboard the ship that has received instructions to conduct the inspection.

The Chief Inspector, usually the commanding officer of the ship, will organize the assisting board. The organization of the assisting board is in general conformance with the departmental organization of the ship. It is divided into appropriate groups, each headed by an inspector with assistant inspectors as necessary. Chief petty officers are usually selected as assistant inspectors, and on small ships, petty officers first class may also be assigned duties as assistant inspectors.

The engineering department inspecting group (or party) will be organized and supervised by the engineer officer. The manner in which the inspection will be carried out will depend to a great extent upon the knowledge and ability of the assistant inspectors.

## General Inspection of the Ship

One of the two categories of the administrative inspection is that of the general administration of the ship as a whole. Items of this inspection that will have a direct bearing on the engineering department, and for which the report of inspection indicates a grade, are as follows:

1. Appearance, bearing, and smartness of personnel.

2. Cleanliness, sanitation, smartness, and appearance of the ship as a whole.

3. Adequacy and condition of clothing and equipment of personnel.

4. General knowledge of personnel in regard to the ship's organization, ship's orders, and administrative procedures.

5. Dissemination of all necessary information among the personnel.

6. Indoctrination of newly reported personnel.

7. General educational facilities for individuals.

8. Comfort and conveniences of living spaces, including adequacy of light, heat, ventilation, and fresh water, with due regard for economy.

## Engineering Department Inspection

The administrative inspection is primarily an inspection of the engineering department paper work, which includes numerous publications, bills, files, books, records, and logs. However, the inspection will also include other items with which the chief and first class will be more concerned. Some of these items are the cleanliness and preservation of machinery and engineering spaces; training of personnel; assignment of personnel to watches and duties; the proper posting of operating instructions and safety precautions; adequacy of warning signs and guards; the marking and labeling of lines and valves; and the proper maintenance of operating logs.

## Administrative Inspection Check-Off Lists

Administrative inspection check-off lists are usually furnished to the ships by the type commander. These lists are used as an aid for inspecting officers and chiefs, to assist them in ensuring that no important item is overlooked. Inspecting personnel should not accept these lists as being all-inclusive. It usually develops, during an inspection, that there are additional items to be considered or observed.

As a CPO, you should be familiar with the various check-off lists used for inspections. The check-off lists will give you a good understanding of how to prepare for an inspection as well as how to carry out your daily supervisory duties. You will find it helpful to obtain copies of the various inspection check-off lists from the log room and to carefully look them over. They will give detailed information for your type of ship.

You can get a better understanding of the scope and purpose of administrative inspections, as compared to other types of inspections, from the following abbreviated sample of an engineering department check-off list:

1. BILLS FOR BOTH PEACE AND WAR:
   a. Inspect the following, among others, for completeness, correctness, and adequacy:
      (1) Department Organization.
      (2) Watch, Quarter, and Station Bills.
      (3) Engineering Casualty Bill.
      (4) Fueling Bill.
2. ADMINISTRATION AND EFFECTIVENESS OF TRAINING:
   a. Administration and effectiveness of training of personnel for current and prospective duties:
      (1) Are sufficient nonrated men in training to replace anticipated losses?
      (2) BuPers training courses:
         (a) Number of men enrolled.
         (b) Percentage of men in department enrolled.

(c) Number of men whose courses are completed.

(3) Are personnel concerned familiar with operating instructions and safety precautions? (Question personnel at random.)

(4) Are personnel concerned properly instructed and trained to handle casualties to machinery?

(5) Are personnel properly instructed and trained in damage control?

(6) Are training films available and used to the maximum extent?

(7) Are training records of personnel adequate and properly maintained?

3. DISSEMINATION OF INFORMATION WITHIN DEPARTMENT:

a. Is necessary information disseminated within the department and divisions?

b. Are the means of familiarizing new men with department routine orders and regulations considered satisfactory?

4. ASSIGNMENT OF PERSONNEL TO STATIONS AND WATCHES:

a. Are personnel properly assigned to battle stations and watches?

b. Are sufficient personnel aboard at all times to get the ship under way?

c. Are men examined and qualified for important watches?

d. Does it appear that men on watch have been properly instructed? (Question personnel at random.)

5. OPERATING INSTRUCTIONS, SAFETY PRECAUTIONS, AND CHECK-OFF LISTS:

a. Inspect completeness of the following:

(1) Operating instructions posted near machinery

(2) Posting of necessary safety precautions

b. Are check-off lists (daily, weekly, monthly, etc.) properly maintained?

c. Are weekly tests and inspections of safety devices properly carried out?

d. Are responsible personnel familiar with current instructions regarding routine testing and inspections?

e. Are lighting-off and securing sheets properly used?

6. Procedures for Procurement, Accounting, Inventory, and Economy in Use of Consumable Supplies, Repair Parts and Equipage:

a. Is an adequate procedure in use for replacement of repair parts?

b. Are there adequate measures used to prevent excessive waste of consumable supplies?

c. Is there proper supervision in the proper supply of, care of, and accountability for hand tools?

d. Are inventories taken of repair parts which are in the custody of the engineering department?

e. How well are repair parts preserved and stowed?

f. What type of system is used to locate a repair part carried on board? (Have a chief or first class petty officer explain to you how he would obtain a repair part for a certain piece of machinery.)

g. Are custody cards properly maintained for accountable tools and equipment?

7. Maintenance of Records and Logs:

a. Inspect the following for compliance with pertinent directives, completeness, and proper form:

(1) Engineering Log.
(2) Bell Book.
(3) Operating Records.
(4) Machinery History.
(5) Current Ship's Maintenance Project.
(6) Alteration and Improvement Program.
(7) Machinery Index.
(8) Daily Oil and Water Records.
(9) Engineering Reports.
(10) Training Logs and Records.
(11) Work Books for Engineering Spaces.

8. Availability and Correctness of Publications, Directives and Technical Reference Material:

a. Engineering Blueprints Recommended:
   (1) Ship's Plan Index (SPI).
   (2) Proper indexing of blueprints.
   (3) Completeness and condition.

b. Manufacturers' Instruction Books:
   (1) Proper indexing.
   (2) Completeness and condition.

c. Type Commanders Material Letters.

d. BuShips *Manual*.

e. General Information Book.

f. Booklet Plans of Machinery.

9. Cleanliness and Preservation:

a. Preservation and cleanliness of space (including bilges).

b. Preservation and cleanliness of machinery and equipment.

c. Neatness of stowage.

d. Condition of ventilation.

e. Condition of lighting.

f. Compliance with standard painting instructions.

## OPERATIONAL READINESS INSPECTION

The operational readiness inspection consists of a demonstration on the part of the ship of her readiness and ability to perform the operations which might be required of her in time of war.

The inspection will consist of the conduct of a battle problem and other operational exercises. A great deal of emphasis will be placed on AA and surface gunnery, damage control, engineering casualty control and other appropriate exercises. Drills such as Man Overboard, Preparations to Abandon Ship, Fire, and Collision will be held and observed. The ship will be operated at full power for a brief period of time.

The over-all criteria of performance will be:

1. Can the ship as a whole carry out her operational functions?

2. Is the ship's company well trained, well instructed, competent, skillful, and adept in all phases of the evolutions?

3. Is the ship's company stationed in accordance with the ship's Battle Bill, and does the Battle Bill meet wartime requirements?

### Observing Party

The personnel and organization of the operational readiness observing party will be about the same as that of the administrative inspection party. However, more personnel are usually required in the operational readiness observing party, and these additional personnel are very often chiefs and first class petty officers.

The observing party members should be briefed in advance of the scheduled exercises and drills that are to be conducted. The observers must have sufficient training and experience so that they can properly evaluate the exercises and drills that are to be held. Each observer will usually have an assigned station. He should be well qualified in the procedure of conducting drills and exercises for that station. It is highly desirable that each observer be intimately familiar with the type of ship to be inspected.

### Battle Problems

In this discussion we will consider the battle problem from the viewpoint of the observer, and present some general information on the requirements and duties of a member of the engineering department observing party. Then, knowing the viewpoint and duties of an observer, you can prepare yourself and your men for a battle problem and other appropriate exercises.

PREPARATION OF A BATTLE PROBLEM. The degree of perfection achieved in any battle problem is a direct reflection of the skill and application of those who prepare it. A great

deal depends upon the experience of officers and chief petty officers.

The primary purpose of a shipboard battle problem is to provide a medium for testing and evaluating the ability of all divisions of the engineering department to function together as a team in simulated combat operations in order to accomplish the mission assigned by the problem.

Battle problems can be made the most profitable and significant of all peacetime training experience, since they demonstrate how ready a department is for combat. The degree of realism of this test governs its value: the more nearly it approximates actual battle conditions, the more valuable it is.

CONDUCT OF A BATTLE PROBLEM. There is one element in conducting a battle problem which increases its value to the ship's company: the element of surprise. Of course, preparations for carrying out a problem can't be kept entirely a secret. Before a battle problem is to be conducted, the ship is furnished information such as:

1. Authority for conducting the inspection.
2. Time of boarding of the inspecting party.
3. Time ship is to get under way.
4. Time for setting the first material readiness condition.
5. Time of conducting inspection for zero problem time conditions.
6. Zero problem time.
7. End of problem time.
8. Time of critique.

Observers should be proficient in the proper methods of introduction of information. In general, information delivered to ship's personnel should be verbal when practicable, and only that information which ship's personnel would logically determine from procedure and adequacy of investigation on search should be furnishd by the observer. Should the inadequacy of procedure by ship's personnel result in the nondiscovery of a casualty imposed, observers may resort to coaching, but a notation should be made on the observer's form as to the time allowed before coaching and information were furnished. Special precautions should be taken to give

the symptoms of casualty the same degree of realism that they would have if the casualty were actual rather than simulated.

In order to impose casualties, valves may have to be closed, switches opened, or machinery stopped. In each case the observer should inform responsible ship's personnel of the action desired, and the ship's personnel should operate the designated equipment. A casualty should be simulated, or omitted entirely, if there is danger that personnel injury or material damage might result because of lack of preparation or experience of personnel concerned. The supply of lubricating oil to the main engines or the supply of feed water to the boilers **MUST NOT** be stopped to simulate casualties.

An emergency procedure is set up, by the observing party and ship's company, to take proper action in case actual casualties—as distinguished from simulated or problem casualties—should occur.

The general announcing system (the 1MC circuit) may be used by the ship but observers normally will have priority in its use. The problem time announcer will use the general announcing system to announce the start of the battle problem, the problem time at regular intervals, the conclusions of the problem, and the restoration of casualties. However, the general announcing system is kept available at all times for use in case of actual emergency. All other announcing system circuits and all other means of interior communications are reserved for the use of the ship.

Engineering telephone circuits should be monitored by one or more observers. A check should be made for proper procedure and circuit discipline, and for handling of information or casualties.

An inspection should be made to see that the engineering plant is properly split in accordance with current directives. Any fire hazards such as paint, rags, or oil should be noted. Check for missile hazards such as loose gear, loose floor plates, tool boxes, and repair parts boxes. The condition of fire fighting, damage control, and remote control gear should be carefully inspected.

**Analysis of the Battle Problem.** The maximum benefit obtained from conducting a battle problem lies in the determination of existing weaknesses and deficiencies, and the resulting recommendations for improvement in organization and future training. Every effort should be made by observers to determine excellencies as well as deficiencies; a knowledge of existing excellencies by ship's personnel is helpful to morale and indicates those factors that presently, at least, may receive less emphasis in the shipboard training program.

Analysis of the battle problem affords the observers an opportunity to present to the ship their opinion of her performance, and for the ship to comment on the observers' remarks and to consider suggested improvements in doctrine or material. Analysis is conducted in two steps; the critique and the observers' reports.

A critique of the battle problem should be held on board the observed ship before the observing party leaves, in order that a review of the problem and the action taken may be made when both are fresh in the minds of all concerned. The critique is attended by all the ship's officers, appropriate chief and first class petty officers, the Chief Observer, and all Senior Observers. The various points of interest of the battle problem are discussed, and the Chief Observer comments on the over-all conduct of the problem after the Senior Observers have completed their analysis of the battle problem as developed from their observers' reports.

The observers' reports will be in the form prescribed by the type commander, and will include any additional instructions given by the Chief Observer. The reports of the observers are collected by the Senior Observer for each department. Senior Observers submit their reports to the Chief Observer. All observers' reports are reviewed by the Senior Observer for the requisite department before the critique is held.

The observers' reports also serve to furnish the inspected ship with detailed observations of the battle problem which

may not, because of time limitations, be brought out during the critique. The inspected ship receives a copy of all observers' reports; in this way, each department is given the opportunity to view the detailed comments and to set up a training schedule to cover weak points.

A brief example of an engineering observer's report form is given as follows:

Engineering Observer ___________________________
Location ___________________________________________

1. The engineering department's evaluation is based on: (a) extent of the department's preparation and fulfillment of the ordered conditions of readiness as appropriate to the problem, (b) extent of correct utilization of the engineering damage control features built into the ship, (c) extent to which proper engineering casualty control is accomplished, (d) extent to which on-station personnel take corrective action for control of damage, (e) adequacy of reports and dissemination of information, and (f) the general handling of the plant in accordance with good engineering practice, and the ability of the department to ensure maximum mobility and maneuverability of the ship and to supply all necessary services to other departments in fighting the ship.

2. Hit _________________

Exercise: _____________

a. Preparation and status of the plant.
b. Fulfillment of proper condition of readiness.
c. Fire and missile hazards.
d. Condition of fire-fighting and damage control gear.
e. Condition of personnel clothing and protection.
f. Stationing and readiness of personnel.
g. Investigation and interpretation of casualty.
h. Promptness and effectiveness in taking care of casualty.
i. Were proper doctrine and procedures used?
j. Were prompting and additional information given by observer?
k. Were proper reports made?

l. Readiness of standby units.
m. Readiness of alternate and emergency lighting and power.
n. Were proper safety precautions observed?
o. Material deficiencies.
p. Coordination of personnel.
q. Coordination of engineering spaces.

3. Main Engine Control. Receipt of vital interior communications, origination and transmissions of required reports to Conn, Damage Control Central, and other stations.

4. Action taken by main engine control:
a. Correct action.
b. Sound judgment based on good practice.
c. Assurance.
d. Speed.

5. Recommendations.

The blank parts of the observers' report forms are filled in as applicable to the individual observer's station. Items that were not observed by him are either left blank or crossed out. Additional information, if required for a certain exercise or condition, may be written on the reverse side of the form. A separate form or sheet is used for each exercise or drill. Remarks or statements made by the observer should be clear and legible.

## MATERIAL INSPECTION

The purpose of material inspection is to determine the actual material condition of the ship in regard to the ability to perform all functions for which the items were separately and interrelatedly designed. On the basis of what the inspection discloses, it may be necessary to recommend repairs, alterations, changes, or developments which will ensure the material readiness of the ship to carry out the mission for which she was designed. In addition, the material inspection determines whether or not proper procedures have been carried out in the care and operation of machinery and equipment. Administrative procedures and material records which are inspected include such items as Material

History Cards, CSMP, and routine tests and inspections.

In brief, the prescribed requirements for material readiness are as follows:

1. Established routines for the conduct of inspections and tests, schedules for preventive maintenance, and a system which will ensure timely and effective repairs

2. Adequate material maintenance records, that are kept in accordance with current directives and that will give the history and detailed condition of machinery and equipment

3. Planned and effective utilization of the ship's facilities for preservation, maintenance, and repair

4. Correct allocation of necessary work to the following categories: (a) the ship's force, (b) the tenders and repair ships, and (c) the naval shipyards or other shore repair activity

The scope of the inspection will be similar to that of inspections made by the Board of Inspection and Survey. The inspection should be thorough and searching, and cover detailed maintenance and repair rather than general appearance. The distinction between administrative inspections and material inspections should be clearly recognized, and there should be as little duplication as possible. An examination of the material maintenance records and reports will be made to obtain data and material history for a proper understanding of the material condition of machinery and equipment. General administrative methods, general appearance, cleanliness of compartments, and cleanliness of machinery are not part of this inspection, except in cases where they have a direct bearing on material condition. Special painting should not be done solely in preparation for material inspection.

The inspecting party for the material inspection is similar to that of the administrative inspection party.

### Preparation for the Inspection

At an appropriate time prior to the date of the inspection the Chief Inspector will furnish the ship with advance instructions, including:

1. List of machinery and major equipment to be opened for inspection. The limit that a unit of machinery or equipment should be opened is that which is necessary to reveal known or probable defects. The units selected to be opened should be representative and, in a multiple-shaft ship, should not disable more than one-half of the propulsion units. Proper consideration must be given to the ship's operational schedule and safety.

2. List of equipment to be operated. Auxiliary machinery such as the anchor windlass, winches, and steering gear are normally placed on this list.

3. Copies of the condition sheets. This is a form of check-off list which is used for the material inspection.

4. Any additional instructions considered necessary by the type commander or other higher authority.

Each department will have to prepare WORK LISTS showing the items of the CSMP which have been assigned for accomplishment by naval shipyard, tender or repair ship, or ship's force during an overhaul or upkeep period. The items must be arranged in the recommended order of importance and numbered according to current directives. A list of the outstanding alterations is also made up for the inspection. Work lists usually consist of 5 by 8 cards, with one repair or alteration item on each card. The work list should include all maintenance and repair items, because material deficiencies found during the inspection will be checked against the work list. If the item does not appear on the work list, a discrepancy in maintaining the CSMP is noted by the inspector.

CONDITION SHEETS. Condition sheets are made up in accordance with different material groups. The engineering department will be primarily concerned with the machinery, the electrical, the damage control, and the hull conditions sheets. Condition sheets contain material in form of check-off sheets and material data sheets, and consist of a large number of pages. Items for data and check-off purposes are listed for all parts of the ship, and for all machinery and equipment on board ship.

In advance of inspection, the ship to be inspected must fill in a preliminary copy of the condition sheets. In order to accomplish this, detailed data must be obtained from the Machinery Index, Machinery History, CSMP, and other records and reports.

An entry of any known fault or abnormal condition of machinery or equipment is made, in the proper place on the conditions sheets. Details and information are given, as necessary, to indicate the material condition to the inspecting party. If corrective work is required in connection with a unit or space, a reference is made to the work list item. Data and information requested in the condition sheets should be furnished whenever possible. The preliminary copy, if properly filled out, will represent the best estimate of the ship as to the existing material condition of the ship.

When the condition sheets have been completed, they are turned over to the respective members of the inspecting party upon their arrival on board ship. During the inspection, the inspectors will fill in the various check-off sections of the condition sheets. These sheets are then used in preparing the final inspection report on the condition of the ship.

For more detailed information concerning your ship, you should obtain a copy of the applicable condition sheets from the engineering log room.

OPENING MACHINERY FOR INSPECTION. The ship will open machinery as previously directed by the Chief Inspector, and as considered desirable, in order to obtain the inspector's opinion concerning known or probable defects. The information given in chapter 6 of BuShips *Manual* should be used as a guide in opening particular machinery units. More detailed information on opening machinery for material inspections will be found in the administrative letters of the type commander.

A list of machinery, tanks, and major equipment opened, and the extent of opening, should be supplied to the inspecting party on its arrival. Test reports on samples of lubricating oil should be furnished to the machinery inspector.

Ship's company should have portable extension lights rigged up and in readiness for the units of machinery opened up for inspection. The lighting of the space should be in good order. The inspectors should be furnished flashlights, chipping hammers, file scrapers, and similar items. Precision measuring instruments should be readily available.

The following abbreviated example is used to give you an idea of the preparation for inspection of material. It is not intended to set up any prescribed method of opening up machinery for inspection.

1. Main Turbines:
   a. Lift at least one-half of the bearing caps.
   b. Furnish a table of the latest bridge gage, depth micrometer, or crown thickness readings; all should be furnished if applicable. Any change from original readings should be noted.
   c. Remove inspection plates from the casings and from the exhaust trunks. Open casings should not be left unattended. Cover plates should be retained in place with 2 or more studs, until the arrival of the inspection party.
2. Auxiliary Turbines:
   a. If any are known to be defective in operation, showing undue vibration, casing leaks, etc., open casing and disassemble, if practicable.
   b. Remove inspection plates, if fitted.
   c. Open half of the bearings, if practicable.
3. Reduction Gears:
   a. Remove inspection plates in the presence of the engineer officer and the inspecting party.
   b. Furnish tables of bearing data.
   c. Have a sample of oil from the bottom of the lubricating oil drain tank ready for the inspecting party.
   d. Lift the caps from one-half of the bearings, when this can be done without lifting the casing.
4. Condensers:
   a. Remove inspection plates or manhole covers from salt-water and steam sides, as far as practicable.

5. Deaerating Feed Tanks:
   a. Remove the inspection plates.
6. Pumps, Reciprocating:
   a. Open the steam and water cylinders and the valve chest of at least one of each type.
   b. Furnish caliper measurements of cylinders, pistons, rods, valve chests, throat bushings, etc. (Cylinders are to be measured fore and aft and athwartships, at top, middle, and bottom of piston travel.)
7. Pumps, Centrifugal:
   a. Lift the casings of one pump of each type, if practicable.
   b. Furnish measurements of internal clearances (wearing rings, etc.).
8. Pumps, Rotary (screw or gear type):
   a. Open one pump of each type, if practicable.
   b. Furnish recent measurements of clearances (rotor, wearing plate, liner, etc., as set forth in chapter 47 of BuShips *Manual*).
9. For all machinery measurements, have constant or design clearances available for comparison with actual readings.

ASSEMBLY OF RECORDS AND REPORTS. The material inspection also includes an inspection of various material records and reports. These documents are assembled so that they will be readily available for inspection. Records should be kept up to date at all times; it is a good idea to check over all records to make sure that they ARE up to date and that nothing has been overlooked. The individual records should be filled out and maintained in accordance with current directives. Where applicable, the CPO who is in charge of an engineering space, or other assignment, should check on any records or reports that concern the material or the maintenance procedures of his space or assignment.

The following is a brief listing of some of the records and reports that are checked and studied by the inspectors:

1. Condition Sheets, filled out for the inspection.

2. Copy of the latest Material Inspection Report by the Board of Inspection and Survey or by Forces Afloat.
3. Weekly Hull Reports.
4. Latest copy of the Docking Report.
5. Material (Machinery) History.
6. CSMP.
7. Machinery Index.
8. Copy of the last Full Power Run.
9. Ship's Allowance Lists, by BuShips.
10. The Work List, prepared for the inspection.
11. The list of outstanding alterations.
12. The latest Ship Characteristics Card.
13. The Ship's Plan Index.
14. Operating Logs.

### Conduct of the Inspection

The inspecting group for the engineering department should conduct a critical and thorough inspection of the machinery and equipment under the cognizance of the department. The condition sheets supplied by the type commander serve as a guide and a check-off list in making the inspection. Appropriate remarks, comments, and recommendations are entered on the condition sheets for the particular unit of machinery or equipment.

The inspectors should conduct the inspection with the ship's personnel. No attempt is made to follow a predetermined inspection schedule, but different units are inspected as they are made available by the ship's company. If the ship is prepared for the inspection there should be no delay between the inspection of the different units of machinery. It is not necessary that all machinery of one type be inspected simultaneously nor is it necessary to complete the inspection of one space before going to another.

Important items to be covered by the inspection are as follows:

1. All opened machinery and equipment should be carefully inspected, especially where the need of repair work is indicated on the work list.

2. An investigation should be made to locate any defects, in addition to those already known, that may exist in material condition or design.

3. Operational tests of machinery and equipment, in accordance with the furnished list, are observed.

4. Ensure that electrical equipment is not endangered by salt water from hatches, doors, or ventilation outlets. Check for possible leaks in piping flanges.

5. Ensure that currently required fire-fighting and damage control equipment in the engineering space is installed and properly maintained in accordance with current directives.

6. Inspect the supports and running gear of heavy suspended material such as boiler sliding feet, condenser saddles, and turbine supports.

7. Inspect holding-down bolts, plates, and other members of machinery foundations. Make free use of hammers for sounding, and of file scrapers for removing paint in order to disclose any condition of metal corrosion.

8. The condition sheets should be checked to see that all the required information has been filled in by the ship being inspected, and that all items have been checked off and filled in by the inspector.

9. Ensure that routine tests of mechanical and electrical safety devices are being conducted according to current directives.

10. The Material History and CSMP should be carefully inspected to see that they are maintained in accordance with prescribed procedures. A check should be made to see that all known repair requirements are listed in the CSMP.

### Analysis and Reports

A critique should be held on board the inspected ship, at a convenient time after the completion of the material inspection, in order that the ship may derive the greatest benefit from the inspection. It should be attended by the ship's commanding and executive officers, heads of departments, and such other personnel as may be designated from the in-

spected ship, the Chief Inspector, and inspectors of each inspection group.

The inspectors, after receiving data from the assistant inspectors, submit reports of their inspections to the Chief Inspector. These reports provide a means of furnishing the inspected ship with those observations that may not be fully discussed during the critique but are of interest to the ship's officers concerned. The inspector's report should include his evaluation and any recommendations for the items inspected or observed. These reports can be used by the ship as a check-off list for corrective action and material improvement.

The Chief Inspector, after receiving the reports from the inspectors, will make up his report, evaluating and grading the inspection. The Chief Inspector should mention, with appropriate comment, the following:

1. Those conditions requiring remedial action which should be brought to the attention of the commanding officer of the ship inspected, and to higher authority.

2. Those conditions of such excellence that their dissemination will be of value in improvements to other ships.

3. Those suggestions or recommendations which merit consideration by higher authority.

The final smooth report is written up in a detailed procedure in accordance with the type commander's directives.

## BOARD OF INSPECTION AND SURVEY INSPECTION

The (Main) Board of Inspection and Survey is under the administration of CNO. This board consists of a flag officer, as president, and of such other senior officers as may be required to assist him in carrying out the duties of the board. Regional boards and sub-boards are established, as necessary, to assist the Board of Inspection and Survey in the performance of its duties. In this discussion we are considering the shipboard inspections that are made by the sub-boards. These sub-boards consist of the Chief Inspector and about 10 or more members, depending upon the type of ship that is to be inspected.

### Material Inspections by Board

The inspection made by the Board of Inspection and Survey is in several respects similar to the Material Inspection that has just been discussed. In fact, the Board of Inspection and Survey's inspection procedure, condition sheets, and reports are used as guides in establishing directives for the Material Inspection. The primary difference, in regard to material inspections, is that the Material Inspection is conducted by Forces Afloat, usually a sister ship, and the Board of Inspection and Survey inspection is conducted by a specially appointed board. This distinction, however, refers only to the routine shipboard material inspection. It must be remembered that the Board of Inspection and Survey conducts other types of inspections which are of a different nature.

Inspections of ships are conducted by the Board of Inspection and Survey, when directed by CNO, to determine their material condition. This inspection usually takes place every 3 to 5 years. Whenever practicable, such inspections should be held sufficiently in advance of a regular overhaul of the ship to permit accomplishment, during such overhaul, of the authorized work resulting from the Board's recommendations. Upon the completion of its inspection the Board will report the general condition of the ship and its suitability for further naval service, together with a list of the repairs, alterations, and design changes which, in its opinion, should be made.

### Acceptance Trials and Inspections

Trials and inspections are conducted by the Board of Inspection and Survey on all ships prior to final acceptance for naval service, to determine whether or not the contract and authorized changes thereto have been satisfactorily fulfilled. These inspections are usually conducted before a new ship is placed in commission. Similar inspections are made on ships that have been converted to other types. All material, performance, and design defects and deficiencies found

to exist, either during the trials or as a result of examination on completion of trials, are reported by the Board, together with its opinion as to the responsibility for correction of defects and deficiencies. The Board will recommend any changes in design which it believes should be made in the ship or in others of its type. Recommendations as to the acceptance or rejection of the ship is made to the Secretary of the Navy.

Unless war circumstances prevent, the preliminary acceptance trial takes place at sea over an established trial course. Tests include full power runs ahead and astern, quick reverse, boiler overload, steering, and anchor engine. During the trial, the builder's personnel usually operate the ship and her machinery. Ship's personnel who are on board to observe the trial should carefully inspect the operation and material condition of machinery and equipment. Any defects or deficiencies should be noted and brought to the attention of division or engineer officer, so that the items can be discussed with the appropriate members of the Board of Inspection and Survey.

### Survey of Vessels

Survey of a vessel is conducted by the Board of Inspection and Survey whenever a vessel is deemed by CNO to be unfit for further service, because of material condition or obsolescence. The Board will, after a thorough inspection, render an opinion to the Secretary of the Navy as to whether the vessel is fit for further naval service, or can be made so without excessive cost.

If the Board believes that the vessel is unfit for further naval service, the Board will make appropriate recommendation as to the vessel's disposition.

## POST REPAIR TRIAL

There are a number of different types of trials which are carried out under specified conditions. To convey a general idea of the different trials, a list comprising most of them is given here:

1. Builder's trials.
2. Preliminary acceptance trials.
3. Final acceptance trials.
4. Post repair trials.
5. Laying up or pre-overhaul trials.
6. Recommissioning trials.
7. Standardization trials.
8. Tactical trials.
9. Full power trials.
10. Economy trials.

The trials that are considered to be routine ship's trials are numbers 4, 9, and 10 of the above list. Post repair, full power, and economy trials are the only ones discussed in this chapter, but information on the other types of trials can be found in chapter 8 of BuShips *Manual*.

The post repair trial should be made whenever the machinery of a vessel has undergone extensive overhaul, repair, or alteration which may affect the power or capabilities of the vessel or the machinery. A post repair trial is usually made when the ship has completed a routine naval shipyard overhaul period; the trial is OPTIONAL whenever machinery has undergone only partial overhaul or repair. The object of this trial is to ascertain if the work has been satisfactorily completed and efficiently performed, and if all parts of the machinery are in every respect ready for service.

The post repair trial should be held as soon as practicable after the repair work has been completed, the preliminary dock trial made, and the persons responsible for the work are satisfied that the machinery is in all respects ready for a full power trial. The conditions of the trial will be largely determined by the character of the work that has been performed. The trial should be conducted in such manner as the CO may deem necessary. In cases where repairs have been slight and the CO is satisfied that they have been satisfactorily performed and can be sufficiently tested without a full power trial, such trial may be dispensed with.

Any unsatisfactory conditions beyond the capacity of

ship's force should be corrected by the naval shipyard. If necessary, machinery should be opened up and carefully inspected to determine the extent of any injury, defect, or maladjustment which may have appeared during the post repair trial.

A certain number of naval shipyard personnel—technicians, inspectors, and repairmen—accompany the ship on a post repair trial. The yard personnel witness the operation of machinery that has been overhauled by the yard. If a unit of machinery is not operating properly, the yard technicians will carefully inspect it and try to determine the cause of unsatisfactory operation.

Upon the completion of the post repair trial, a report of the circumstances and results of the trial is made to CNO and to BuShips.

## FULL POWER AND ECONOMY TRIALS

Trials are necessary to test engineering readiness for war. Except while authorized to disable or partially disable, ships are expected to be able to conduct prescribed trials at any time. Ships normally should be allowed approximately a 2-week period after tender overhaul, and a 1-month period after shipyard overhaul, to permit final checks, tests, and adjustments of machinery before being called upon to conduct a competitive trial.

Trials are also held from time to time to determine machinery efficiency under service conditions, the extent of repairs necessary, the sufficiency of repairs, and the most economical rate of performance under various conditions of service.

### Inspections and Tests Prior to Trials

The full power and the economy trials, as discussed in this chapter, are considered in the nature of competitive trials. It is assumed that the ship has been in full operational status for sufficient time to be in a good material condition and to have a well-trained crew.

Prior to the full power trial, inspections and tests of machinery and equipment should be made to ensure that no

material item will interfere with the successful operation of the ship at full power. The extent of the inspections and the tests will largely depend upon the recent performance of the ship at high speeds, the material condition of the ship, and the time limits imposed by operational commitments.

The inspection and tests of boilers, main engines, pumps, auxiliary machinery, safety devices, piping systems, and all equipment necessary for the proper operation of the engineering plant should be made as prescribed in those chapters of the BuShips *Manual* which contain detailed instructions for the various units of the plant or, in the absence of specific instructions, as the dictates of good engineering practice may require.

Not later than one day before a trial, the engineer officer should report to the CO the condition of the machinery installation, stating whether or not it is in proper condition and fit to proceed with the trial, or wherein any part is, in his opinion, not in a safe and proper condition.

### General Rules for Trials

During all full power trials, and during other machinery trials to which they may be applicable and consistent with the conditions imposed, the following general rules should be observed:

1. The speed of the engines should be gradually increased to the speed specified for the trial. Prior to commencing a power trial, the machinery should be thoroughly warmed up; this can be accomplished by operating at a high fractional power.
2. The machinery should be operated economically, and designed pressures, temperatures, and number of revolutions must not be exceeded.
3. The full power trial should not be conducted in SHALLOW WATER, which is conducive to excessive vibration, loss of speed, and overloading of the propulsion plant. Detailed information on the proper depth of water for your ship may

be obtained from chapter 8 (article 8–115) of BuShips *Manual*.

4. If it is desirable to continue a full power trial beyond the length originally specified, the observations should be continued until the trial is finished. The four hours, or any other predetermined time, of the trial should be continuous and without interruption. If a trial at constant rpm be discontinued for any reason, that trial should be considered unsatisfactory and a new start made. No major changes of the plant set-up or arrangement should be made during economy trials.

### Under Way Report Data

Reports of trials should include all the attending circumstances, especially draft forward, draft aft, mean draft, and corresponding displacement of the ship at the middle of the trial; the condition of the ship's bottom; the last time drydocked; the average horsepower developed by the main engines; the consumption of fuel per hour, per mile, and per shaft horsepower on indicated horsepower of the main engines per hour; the average speed of the ship through the water; and the average revolutions of the propelling engines. The methods by which the speed and shaft horsepower were determined should also be described.

This report should also include a tabulation of gage and thermometer readings of the machinery in use, and revolutions or strokes of pertinent auxiliaries. The auxiliaries in use during the trial should be stated. The report should state whether the machinery is in a satisfactory condition. If its condition is found to be unsatisfactory, all defects and deficiencies should be fully described and recommendations made for correcting them.

### Trial Requirements

Trial requirements for each ship, covering the revolutions per minute for full power at various displacements and injection temperatures, are furnished to commanders and units

concerned, by the Chief of Naval Operations (Operations Readiness Division). The rpm for 15, 20, and 25 knots is also furnished for the appropriate ships.

Full power trials are of 4 hours duration, as far as the report data are concerned. The usual procedure is to operate the ship at full power for a sufficient length of time until all readings are constant, before starting the official 4-hour trial period. The smoke prevention trial (Diesel-driven ships excepted) should be the last hour of the full power trial and should be run at the same speed. Economy trials are of 6 hours duration, a different speed being run at each time a trial is made.

Trials once scheduled should be run unless prevented by such circumstances as:

1. Weather conditions which might cause damage to the ship
2. Material trouble which forces the ship to discontinue the trial, or which might cause damage to the machinery if the trial were continued
3. Any situation such that running or completing the trial would endanger human life

If a trial performance is UNSATISFACTORY, the ship concerned will normally be required to hold a retrial of such character as the type commander may consider appropriate to demonstrate satisfactory engineering readiness.

The fact that a ship failed to make the required rpm for any hour during the trial, and the amount by which it failed, should be noted in the trial report. Similarly, the number of seconds smoke was observed during the smoke prevention trial should be noted.

### Observation of Trials

When full power trials are scheduled, observing parties should be appointed from another ship whenever practicable. When a ship is scheduled to conduct a trial while proceeding independently between ports, or under other conditions where it is considered impractical to provide observers from another

ship, the ship under trial may be directed to appoint the observers. For economy trials, observers may be appointed from the ship under trial.

The number of personnel assigned to the observing party will vary according to size and type of ship. The duties of the observing party are usually as follows:

1. The Chief Observer will organize, instruct, and station the observing party. He checks the ship's draft, either at the beginning of the trial or before leaving port; supervises the performance of the engineroom observers; checks the taking of counter readings; renders all decisions in accordance with current directives; and checks and signs the trial report.

2. The Assistant Chief Observer assists the Chief Observer as directed; supervises the performance of the fireroom observers; checks the taking of fuel oil soundings and meter readings; observes smoke as required; and makes out the trial report.

3. Assistant observers take fuel soundings and meter readings, counter readings, the ship's draft, and other data as may be required for the trial report.

The following items should be accomplished or considered before starting the trial:

1. When requested by the observing party, the ship under trial should provide or designate a suitable signaling system so that fuel soundings and the readings of counters and meters may be taken simultaneously.

2. The ship under trial should furnish the Chief Observer with a written statement of the date of last undocking, and the authorized and actual settings of all main machinery safety devices and dates when last tested. The ship should have its draft, trim, and loading conform to trial requirements. In case a least draft is not specified, the liquid loading should equal at least 75 percent of the full load capacity.

3. The Chief Observer should determine draft and trim before and after the trial. He should verify the amount of fuel on board and correct this amount to the time of beginning the trial. He should determine the rpm required for

the full power trial, at the displacement and injection temperature existing at the start of the trial.

4. The observing party should detect and promptly correct any errors in recording data, since it is important that the required data be correct within the limits of accuracy of the shipboard instruments.

5. The Chief Observer should require members of the observing party to detect any violation of trial instructions, of instructions in BuShips *Manual*, or of good engineering practice. The Chief Observer should verify any such report and then inform the commanding officer of the ship under trial. He should also include in the trial report a detailed account of any violation.

### Manner of Conducting Trials

Some of the requirements in regards to the manner of conducting full power and economy trials are as follows:

1. Unless otherwise ordered, a full power trial may be started at any time on the date set, provided sufficient time remains so that the smoke-prevention run (if required) may be held during daylight.

2. The trial should be divided into hourly intervals, but readings should be taken and recorded every half hour. Data is submitted as hourly readings in the trial report.

3. Fuel expenditures for each hourly interval of the trial should be determined by the most accurate means practicable, normally by meter readings corrected for meter error and verified by soundings.

4. During the smoke-prevention run, the smoke pipes should be continuously observed by an officer. He should record in seconds the time during which smoke may be observed.

5. The appropriate material condition of the ship should be set during the different trials.

6. During all trials the usual "housekeeping" and auxiliary loads should be maintained and the minimum services provided should include normal operation of the distilling

plant, air compressor, laundry, galley, ventilation systems, elevators (if installed), and generators for light and power under load conditions similar to those required for normal operations at similar speeds under the prescribed material condition.

7. All ships fitted with indicators, torsionmeters, and other devices for measuring shaft or indicated horsepower should make at least two observations during the full power trial to determine the power being developed.

8. The Chief Observer should state in his report of the trial whether all rules for the trial have been complied with.

### Some Hints in Regard to Full Power Trials

There are special forms used for full power and economy trial reports. Since illustrations of these forms are not given in this training course, it is advisable to obtain copies of these report forms from your log room, to get some idea of the data and readings that will be required for full power and economy trials.

Trial forms, and such items as tachometers, stop watches, and flashlights, should be available to the observing party and to the personnel who take readings. Any gages or thermometers which are considered doubtful or defective should be replaced before trials are held. Usually a quartermaster will check and adjust all clocks in the engineering spaces and on the bridge before any trials are held.

It is a common procedure of many commanding officers, when making full power trials, to bring the ship up to a speed of one or more knots below the trial run speed of the ship. Then the control of the speed (except in cases of emergency nature) of the ship is turned over to the engineer officer. The control engineroom, under the supervision of the engineer officer, will bring the speed up slowly, depending upon the conditions of the plant, until the specified speed has been reached. In view of the fact that for most ships the designed boiler power is the first factor that establishes the maximum speed that a ship can attain, it is a good policy

to check boiler steaming conditions before ringing up additional turns. The boilers should not be loaded down faster than they are capable of taking care of the increased load. The steam pressure and temperature should be kept at full value for the appropriate steaming condition. In other words, the turbines must not get ahead of the boilers. The boilers should be the controlling factor and should be kept ahead of the turbines. If the turbines are allowed to get ahead of the boilers, the main steam pressure and temperature will drop below normal values for that particular steaming condition, or speed of the ship. Then, in order to make up this loss in steam pressure and temperature and to meet additional increases of speed that may be rung up, the boilers must be fired at an extremely high rate. In some ships, this firing rate may exceed the full load rating of the boiler and approach the maximum 120 percent overload capacity rating of the boiler. As far as the engineering plant is concerned, the primary purpose of the acceleration curve or table is to prevent the overloading of boilers. The use of the acceleration curve is of particular importance when accelerating near full speed and full power.

## SUMMARY

As an MM1 or C aboard ship, you will be concerned with a number of inspections—administrative inspections, material inspections, operational readiness inspections, and inspections held by the Board of Inspection and Survey. Whether you, as an assistant inspector, are a part of the inspecting party, or some other person performs the inspection, you will need to know how the inspections are conducted. At all times, you must bear in mind that you should be prepared for an inspection aboard your ship.

Administrative inspections cover administrative methods and procedures normally employed in the engineering department. The purpose of such inspections is to determine (1) that the department is being administered in a sound and efficient manner, and (2) that the organizational and admin-

istrative methods and procedures are directed toward preparing every naval vessel to carry out her assigned mission.

General instructions for conducting an inspection are usually given by the division commander. However, the selecting and organizing of the inspection party is done aboard the ship that has been instructed to conduct an inspection on another ship within the division.

Operational readiness inspections provide your ship with an opportunity to demonstrate her readiness and ability to perform the operations that would be required of her in time of war. The inspections consist of a battle problem and other operational exercises.

The primary purpose of a shipboard battle problem is to provide a medium for testing and evaluating the ability of all divisions of the engineering department to work together as a team in simulated combat operations. You should direct all your preparations and drills toward that objective. This means constant and coordinated drills aimed at making your organization proficient in handling casualties.

The scope of the material inspection will be similar to that of inspections made by the Board of Inspection and Survey. The inspection should be thorough and searching, and cover detailed maintenance and repair rather than general appearance. An examination of the material maintenance records and reports will be made to obtain data and material history for a proper understanding of the material condition of machinery and equipment. General administrative methods, general appearance, cleanliness of compartments, and cleanliness of machinery are not part of this inspection, except insofar as they may have a direct bearing on material condition.

Be prepared for a critical examination, by the inspection party of the Board of Inspection and Survey, of all material under your control. The inspector may require that the designated machinery be operated, if conditions warrant it. He may review the "operating records," the Machinery History, and the CSMP.

Full power and economy trials of naval vessels should be made for the purpose of ascertaining the capabilities and efficiency of the machinery installation. Trials are held from time to time to determine their efficiency under service conditions, the extent of repairs necessary, the sufficiency of repairs, and the most economical rate of performance.

## QUIZ

1. When may a first class or chief MM be assigned to duty as an assistant inspector aboard a ship?
2. What type of inspection is used to determine that all divisions of the engineering department are being administered in an intelligent, sound, and efficient manner?
3. Who organizes and supervises the engineering department inspecting group?
4. Who generally supplies a ship with administrative inspection check-off lists?
5. What type of inspection consists of the conduct of a battle problem and other operational exercises, with emphasis on gunnery, and damage control?
6. What is the primary purpose of a shipboard battle problem?
7. In conducting a battle problem, what element increases its value to the ship's company?
8. When a battle problem is being conducted, what method should an observer use to deliver information to ship's personnel?
9. During the conduct of a battle problem, when may observers resort to coaching ship's personnel?
10. If it becomes necessary, during the conduct of a battle problem, to close valves, open switches, or stop the machinery, who should operate the designated equipment?
11. What provision is made for handling actual casualties which might occur during a battle problem?
12. The problem time announcer will use the 1MC circuit to announce what facts during a battle problem?
13. What announcing system circuit is kept available at all times for use in case of actual emergency?
14. Why is it important for observers to determine excellencies as well as deficiencies, in the analysis of a battle problem?
15. Analysis of a battle problem is conducted in what two steps?
16. What type inspection conducted by another ship determines whether or not proper procedures have been carried out in the care and operation of machinery and equipment?

17. When is cleanliness of machinery a part of the material inspection conducted aboard ship?
18. In a multiple-shaft ship, what is the maximum percent of machinery and major equipment units which can be disabled for a material inspection?
19. In preparation for an inspection, the engineering department is primarily concerned with what condition sheets?
20. Who should attend a critique held on board the inspected ship after a material inspection of equipment and machinery has been completed?
21. What is the primary difference between the material inspection and the Board of Inspection and Survey inspection?
22. In order to determine the material condition of ships, how often are inspections usually conducted by the Board of Inspection and Survey?
23. Who is responsible for conducting trials and inspections on all ships prior to final acceptance for naval service, to determine whether or not the contract and authorized changes thereto have been satisfactorily fulfilled?
24. During a preliminary acceptance trial at sea, which personnel generally operate the ship and her machinery?
25. What are considered three routine ship's trials?
26. Why should inspections and tests of machinery and equipment be made prior to the full power trial?
27. Why should a full power trial NOT be conducted in shallow water?
28. No major changes of the propulsion plant set-up or arrangement should be made during which routine ship's trials?
29. What is the duration of a full power trial, as far as the report data is concerned?
30. Who generally supervises the performance of engineroom observers during full power trials?
31. Who determines the rpm required for the full power trial, at the displacement and injection temperature existing at the start of the trial?
32. In conducting a full power trial, how often should readings be taken and recorded?
33. In general, what is the first factor that establishes the maximum speed which a ship can attain?
34. At a given speed, if the turbines are allowed to take too much steam from the boilers, how will the main steam pressure and temperature be affected?
35. As far as the engineering plant is concerned, what is the primary purpose of the acceleration curve?

## APPENDIX I

# ANSWERS TO QUIZZES

## CHAPTER 1

## LEADERSHIP AND ORGANIZATION

1. In the *Manual of Qualifications for Advancement in Rating*, NavPers 18068 (Rev. 1952).
2. Personnel relations.
3. To be a leader.
4. Knowledge, skill, and tactful handling of men.
5. WHAT is to be done, WHEN it is to be done, HOW it is to be accomplished (if instructions are necessary), and WHY it must be done (when practicable to explain).
6. To catch mistakes before they may result in excessive loss of time, labor, and material.
7. Charts, diagrams, training films, working models, and slides.
8. The organization of your ship, your department, and your division.
9. Officer of the deck.
10. Officer of the deck and the engineer officer.
11. Ship's Organization Book.
12. Chief Machinist's Mate.
13. Every 30 minutes; by the engineroom auxiliary watch.
14. Information concerning the status of the machinery in operation, orders, special orders, and uncompleted orders.
15. Once a week, usually on Friday.
16. A cold-iron watch.
17. To maintain a designated water level in the boiler.
18. The number of burners, the size of the sprayer plates, and the oil pressure carried.
19. The pumpman.
20. The messenger.

## CHAPTER 2

## PROPULSION TURBINES

1. To permit adjustment of the oil flow to all journal and thrust bearings.
2. 50° F.
3. The viscosity of the oil being used, the design of the bearing,

the running speed, the clearances, and the location and accuracy of the thermometer.

4. The quality and quantity of the oil to that bearing.
5. The throttle should be closed immediately and the shaft stopped.
6. A bowed rotor, a defective thrust bearing, burned out journal bearings, or foreign matter inside the turbine casing.
7. Part of the blading has been damaged.
8. Once each quarter.
9. Once each quarter.
10. Once each quarter.
11. The clearance between the rotor and the casing.
12. Manufacturer's instruction book and plans.
13. Rebabbitt or replace the bearing, if necessary.
14. Remove the collar for repairs or replacement.
15. The thickness of the filler piece.
16. Ship's force.
17. Furmanite and copaltite.
18. Because they have seats and disks with spherical contours.
19. Shipyard personnel.
20. About every 5 years.
21. The past performances of the particular type of turbine, data furnished by the CO of the ship, and recommendations made by the forces afloat.
22. Oil is circulated through the bearings, the rotor jacked slowly, and a check made for any unusual sounds.
23. Usudurian.
24. Acetylene torch.
25. The repair activity doing the work.
26. Slow down, investigate, and endeavor to locate the cause.
27. About 24 hours after securing, and when the turbine is thoroughly cooled.

## CHAPTER 3

# MAIN REDUCTION GEARS

1. The articulated gearing.
2. The nested type reduction gear.
3. The locked train double reduction gear.
4. BuShips.
5. At a naval shipyard, or similar activity.
6. The temperature is increased.
7. The turbine rotors may be bowed.
8. At low shaft rpm when maneuvering or while operating in very shallow water.

9. A complete investigation should be made, preferably by a naval shipyard.
10. Bent shafts, damaged propellers, and improper balance.
11. Misalignment of the turbines and main shafting as well as the main gear foundation.
12. Naval shipyard personnel.
13. Secure the shaft and reduction gear until the units can be inspected and repaired by a repair activity.
14. The high-speed pinion bearings.
15. To see that the inside of the gear is free of any foreign matter, such as dirt or tools.
16. Misalignment or improper lubrication.
17. The pinion and gear shaft will not be parallel.
18. The length of tooth contact across the face of the pinions and gears (also satisfactory wear or meshing of the gear teeth).
19. Prussian blue.
20. 80 percent.
21. When removing a local hump or deformation.
22. Two sets.
23. Because the base rings could tilt under the freedom given by the leveling plates and a false reading would be obtained.
24. The thrust shoe surfaces should be examined, and repairs made if necessary.
25. Take readings while running the turbines slowly ahead and astern.
26. Micrometer depth gage.
27. At least once each quarter.
28. The gears should be stopped immediately and not operated until the cause of the trouble can be found and remedied.
29. The engineer officer.

## CHAPTER 4

# CONDENSERS AND HEAT EXCHANGERS

1. Condensate depression.
2. Whenever the water chest manhole, or handhole covers, are removed for cleaning condensers or zincs.
3. By thoroughly and continuously draining the lines at all low points.
4. Empty and drained.
5. Once each month, or immediately after an extended cruise.
6. Once each quarter, when the inspection covers are removed from the low-pressure turbine.
7. A loose zinc plate or a foreign object inside the header.

8. By boiling out with a strong solution of Navy standard boiler compound.
9. Every 2 or 3 years.
10. Deterioration of the tube wall which starts at the sea-water side and proceeds through the tube wall to the steam side.
11. 10 percent.
12. All interior parts of the condenser shell (stay rods, hot well, internal baffles, and joints).
13. Excessive cold-worked stresses in the metal, which contribute largely to rapid tube end erosion and/or corrosion.
14. The joint should be recalked with light hammer blows applied to the calking tool.
15. 15 psi.
16. The engine should be slowed down or stopped.
17. "Necking" or crimping tubes.
18. Open the steam and water supply valves slowly.
19. An orifice.
20. 2⅛ inches.
21. At least once each month, when new; thereafter every six months.
22. A loss of vacuum.
23. At least semiannually.
24. In the uppermost point of the line.
25. The thermostatic recirculating valve.
26. 120° to 130° F.
27. (1) Erosion due to high sea-water velocity, and (2) corrosion due to electrolytic (or galvanic) action.
28. When they are 50 percent disintegrated.

## CHAPTER 5

# SHIP'S SERVICE TURBOGENERATORS

1. To operate the pilot valve which controls the flow of oil to the operating cylinder.
2. When there is an increased load on the generator, causing the turbine to slow down.
3. When a generator turbine is started, it is subject to variable expansion movements because of changing temperature and load condition.
4. 180° F.
5. To guard against steam bleeding into the turbine casing.
6. After each period of steaming, and at least once each quarter.
7. When a turbine is new, or after extensive repairs have been made to the unit.

8. The turbine should be slowed down, but kept turning over at a low speed until the bearings and journal have cooled sufficiently.
9. The bearings, the lines, and the reservoir.
10. The valve seats should be seal-welded or silver-soldered in place.
11. 15 minutes.
12. They should be sent to the factory to be retested and repaired.
13. A test should be conducted to assure proper functioning of the unit.
14. A thorough investigation should be made to determine the cause(s) of the trouble.
15. By studying the various illustrations and the unit itself.
16. Make certain that the pilot-valve bushing is removed.
17. Once each day.
18. Once each week.
19. Once each quarter, and whenever the turbine is put into operation after having been permanently secured.
20. Once each day, and before admitting steam to the casing.

## CHAPTER 6

# PUMPS

1. Operating the pump at full stroke.
2. Long stroke.
3. By means of the tappet collars.
4. By removing the piston and plunger, and running a line through the cylinders.
5. By jacking the pump with a bar.
6. Rust.
7. Soak the packing in water overnight.
8. Faulty piston rings.
9. Lack of proper lubrication.
10. At least twice each year.
11. Once each quarter.
12. 10 percent.
13. Dismantle the rotor completely to determine and correct the individual part which is out of balance.
14. Short in capacity.
15. The pump is overloading the driver.
16. Case rings and impeller rings, shaft sleeves, and bearings.
17. The pump should be stopped and the cause of excessive vibration located.
18. Capacity too low, pressure too low, no water, speed too low, low suction pressure, and foreign matter in the casing or impeller passages.

19. To obtain any information available regarding past alteration of the pump's construction.
20. (1) The amount of steam to be condensed, (2) the temperature of the circulating water, and (3) the vacuum that is being maintained on the condenser.
21. Remove the drive.
22. The housing guide pins must be removed.
23. The manufacturer's pamphlet or blueprint.
24. The proper locating cap settings.
25. The mountings and the drive details affected by the mountings.
26. 5 percent.
27. To control steam pressure admitted to the pump propulsion unit, so as to maintain the fluid discharge at a constant preset level.
28. Adjustment of the needle valve.
29. The pilot valve is continuously throttling the steam which passes through it.
30. At least once each quarter.

## CHAPTER 7

# PROPULSION PLANT OPERATION AND SUPERVISION

1. To indoctrinate, train, and prepare ship's crews for wartime conditions and operations.
2. Inexperienced and improperly trained personnel.
3. When there is no engineering officer on watch aboard ship.
4. To create and maintain readiness to deliver the designed performance of the engineering plant at all times.
5. Fuel performance ratio.
6. When personnel are on steaming watch stations.
7. Acceleration, deceleration, and the operation of the main condenser.
8. By proper insulation.
9. Good insulation, elimination of all steam leaks, and a clean ventilation system.
10. Uneconomical operation of the engineering plant.
11. At least twice a day.
12. The first part of the engineroom lighting-off sheet.
13. When all the watch standers have mustered in the engineroom.
14. Fireroom and engineroom.
15. Two-furnace single-uptake superheat-control boilers.
16. 400 to 460 psi.
17. From 1 to 2 hours.
18. When ordered by the engineer officer and when the superheater protection device indicates a safe steam flow through the superheaters.

19. 600° F.
20. When permission has been received from the OOD.
21. The MMC in charge of the watch.
22. Prior to entering port or coming to anchor.
23. 50° F every 5 minutes.
24. The degree of superheat.

## CHAPTER 8

# ENGINEERING CASUALTY CONTROL

1. In the Engineering Casualty Control Book.
2. By the elimination of weaknesses which lead to material failure, and by the installation of alternate or standby means for supplying vital services.
3. Abnormal operating speeds, pressures, temperatures, vibrations, and noises.
4. They should all be inspected to determine whether there is danger of the same type of failure.
5. Oil-lubricated ball bearings.
6. CO.
7. That there is risk of even greater damage, or loss of ship, in immediately securing the affected unit.
8. Accurate information.
9. Limitation of the effects of the damage, emergency restoration, and complete repair.
10. At all times when not in use.
11. The officer or CPO in charge of the engineering watch.
12. Close the guarding valve or the main line stop valve.
13. The astern steam pressure and the ship's rpm on the other shaft(s), when the shaft is held stationary for locking.
14. When the shaft is locked for more than 5 minutes.
15. The pressure of water in the casing, either from boiler priming or from inadequate casing drainage.
16. Wiped reduction gear bearings result in uneven gear wear.
17. Disconnect the cruising turbine, insert the locking device, secure valves, gland seal, gland leak-off, and cruising turbine drains.
18. Check the condensate pump, the recirculating valves, and the water level in the main condenser.
19. Localized overheating and probable slight wiping of one or more bearings.
20. The cruising turbine bearings.
21. The main reduction gear bearings.

22. When the high-pressure and the low-pressure turbine bearings are wiped.
23. Obtain permission from the OOD to slow the engine, pump down sump tank to the proper level, and determine and remedy the cause of the trouble.
24. The Machinist's Mate should check the inspection tank, and if oil has carried through, shift the inspection tank drain to the bilges.
25. The Machinist's Mate should see that water is added to the deaerating feed tank.
26. Whether the ship is steaming split-plant or cross-connected.
27. Temporary securing of the boiler may be required.

## CHAPTER 9

# DAMAGE CONTROL ORGANIZATION AND SUPERVISION

1. Organization.
2. Administrative and battle organization.
3. (1) to take all practical preliminary measures before damage occurs, (2) to minimize and localize damage, and (3) to accomplish emergency repairs or restorations as quickly as possible after damage occurs.
4. Because the ability of a ship to accomplish an assigned mission may depend upon the effectiveness of damage control measures.
5. By a thorough study of the ship and the various systems, and by a study of methods successfully used and of mistakes made by other ships in combating damage.
6. From the ship's damage control officers or from chapter 88, article 88–505, of BuShips *Manual*.
7. Ship's Organization Book.
8. To permit dispersal of personnel and a wide coverage of the assigned areas.
9. In a central and well-protected location.
10. To collect and compare reports from the various repair parties in order to determine the condition of the ship and the action that should be taken.
11. The repair party.
12. Diagrams kept at Damage Control Central and at various repair party stations.
13. The effectiveness of the individual repair party.
14. (1) The locale of the station, (2) the portion of the ship assigned to that party, and (3) the total number of men available for all stations.

15. The complement of the ship.
16. To maintain proper condition of closure.
17. To remote control stations in the assigned area.
18. Only the members of the repair parties.
19. Battle telephone circuits (sound-powered), interstation two-way systems (4MC intercoms), ship's service telephones, ship's loud-speaker system (1MC general announcing), voice tubes (where installed), and messengers.
20. 2 JZ.
21. The 3, 4, 5, 6, and 7 JZ circuits.
22. X40J.
23. They are not part of the battle system, and may go out of commission early in action.
24. Too many stations other than damage control are affected.
25. In the event a repair station succeeds to control for damage, it must know what casualties all other stations are handling in order to assume control intelligently.
26. To isolate damaged or short-circuited portions of a circuit, thus restoring the remainder of the circuit to use.
27. Knowledge, leadership, and training.
28. The second senior man.
29. These men may become injured and the resulting loss will cause confusion.
30. By inserting shorting-out plugs.

## CHAPTER 10

# DISTILLING PLANTS

1. Three-effect or triple-effect.
2. The MM1 or C in charge of the distilling plant.
3. Full output cannot be maintained.
4. 16 inches Hg vacuum to approximately atmospheric pressure.
5. To ensure keeping scale formation to a minimum, and to maintain full capacity for long periods of time.
6. Air leakage, improper water levels in evaporator shells, improper venting of evaporator tube nests, scale deposited on evaporator tubes, and improper draining of evaporator tube nests.
7. Capacity and economy losses.
8. By means of the compound gage and the thermometed which are installed on the steam head of the first-effect tube nest.
9. Improper venting of the evaporator tubes.
10. The output of the plant will be reduced considerably.
11. When the tube nest vacuum approaches zero.
12. 1.5 thirty-seconds.

13. Flooding of the gage glass on the tube nest drainer.
14. Air leaks.
15. Insufficient steam pressure or wet steam at the air ejector nozzle.
16. By means of the special nozzle reamers.
17. The distilling condenser vacuum.
18. When the plant is properly operated and a full flow of circulating water is maintained.
19. The MM 1 or C.
20. Check the readings of the various thermometers and gages.
21. The operational procedures and the material conditions.
22. At least once every 6 months (preferably every 3 months).
23. By means of an air pressure or a hydrostatic test (in accordance with the recommended procedures in the manufacturer's instruction book).
24. Naval shipyard.

## CHAPTER 11

# REFRIGERATION MAINTENANCE AND REPAIR

1. Every hour.
2. At least once each month.
3. Presence of leaks.
4. Halide torch.
5. Refrigeration repair personnel at naval shipyards or aboard repair ships.
6. The size of the system and the amount of moisture present in the circuit.
7. (1) Excess moisture in the system, (2) absorbed Freon in crankcase oil, (3) leakage of air into the system, (4) inefficient vacuum pump or defective vacuum indicator.
8. Immediately after each period during which the dehydrator has been used.
9. By removal of the drying agent and heating it, for several hours, to a temperature of 250° to 350° F.
10. The compressor crankcase is under a slight pressure.
11. After each cleaning of the compressor suction scale trap.
12. Either a gradual or a sudden decrease in the normal compressor capacity.
13. By pumping down the compressor to 2 psi gage, then stopping the compressor, and quickly closing the suction and discharge line valves.
14. After the compressor has been in operation for a minimum of 3 days.

15. Moisture-laden air will be drawn into the system.
16. All parts should be carefully washed in carbon tetrachloride and permitted to dry in air. The final rinse should be made with clean carbon tetrachloride. Care should be taken to prevent dirt, lint, water, or other foreign matter from entering the compressor during reassembly.
17. After the condenser has been properly purged.
18. At least once every two weeks.
19. Thermostatic expansion valve.
20. An insufficient amount of Freon–12 will be admitted to the cooling coil and the coil will operate at reduced capacity.
21. The low-pressure cut-out, the cooling thermostat, and the water failure switches.
22. Regulate expansion valve and check thermal element attachment.
23. Stop the compressor, check oil gage for accuracy, pump down, and clean oil lines.
24. Shortage of refrigerant.
25. Sterile mineral oil or olive oil.

## CHAPTER 12

# AIR CONDITIONING

1. To keep the ship's personnel comfortable, alert, and physically fit at battle stations.
2. Saturated air.
3. The higher the temperature, the more moisture the air can hold.
4. The weight of water vapor in grains per pound of dry air.
5. The ability of the air to evaporate liquid moisture is indirectly indicated by the relative humidity.
6. Sensible heat and latent heat.
7. When the air is saturated.
8. 52 percent.
9. By radiation, convection, conduction, and as a byproduct of physiological processes taking place within the body.
10. When the heat is carried away from the body by convection currents, both by the air coming out of the lungs and by exterior air currents.
11. About 45 percent by radiation, 30 percent by convection and conduction, and 25 percent by evaporation.
12. Effective temperature.
13. 50 to 60 percent.
14. The ranges of temperatures, relative humidities, and air velocities which produce a normal feeling of comfort for most persons.
15. Cooling water by evaporation.

16. To remove the flashed vapor from the flash tank and send it to the condenser.
17. The lithium bromide plant.
18. The concentration and temperature of the solution.
19. To improve the efficiency and reduce cooling water consumption.
20. Refrigerating system using mechanical compression.
21. At least once a week.
22. In the air conditioning system there is a larger pressure drop in the cooling coil.
23. 60 psi.
24. Every two hours.
25. At least once each week.

## CHAPTER 13

# PIPING SYSTEM REPAIR AND MAINTENANCE

1. Once each quarter.
2. Graphite or asphaltum paint.
3. A dangerous blowout may result from progressive growth of the leak.
4. By brazing.
5. With sheet lead or with some other soft material.
6. Copper-nickel alloy piping.
7. The valve should be made tight by grinding the disk together with the seat.
8. Salt-water lines.
9. They should be refaced either in a lathe or with a reseating tool.
10. To ensure that the guides in the valve bonnet align properly with the guides in the valve body.
11. With the stem pointing straight upward.
12. The purpose for which it is used.
13. At least once each week.
14. Steam traps must be located below the lowest point to be drained and should be placed so as to be easily accessible for inspection and repair.
15. The ball-float traps are larger, heavier, and have additional working parts.
16. Secure the parts in place with additional securing devices to prevent repetition of the trouble.
17. Once each quarter.
18. About 3 percent.
19. The main and auxiliary steam lines, including the 150-psi lines, and whistles and sirens.
20. The steam traps and bypasses.

## CHAPTER 14

# LATHE MACHINING OPERATIONS

1. 30°.
2. A narrow cut is made at each end of the work and then the diameters are compared by measuring with calipers.
3. Facing the ends of the work.
4. In the direction of the head spindle.
5. It eliminates need for frequent measuring, and thus speeds up production.
6. $\frac{1}{16}$ of an inch.
7. When the work has been rough turned to within approximately $\frac{1}{32}$ inch of the finished side.
8. Making accurate measurements.
9. By locating the shoulder with a parting or cut-off tool.
10. The piece to be bored must have a pilot hole, drilled or cored, large enough to receive the boring tool.
11. The boring tool is fed to the work.
12. Taper.
13. $\frac{1}{2}$-inch taper per foot.
14. The included angle of the taper is twice the angle that the surface makes with the axis or centerline.
15. Morse taper.
16. Tailstock set-over method.
17. $\frac{1}{2}$ inch.
18. At an angle to the axis of the lathe.
19. Compound rest feed screw.
20. The American National Screw Thread.
21. The lathe dog must not be removed from the work and the dog must be replaced in the same slot of the driving plate.
22. Make sure that the chuck jaws are tight and the work is well supported. The chuck must be tight enough on the spindle and the work should not be removed from the chuck until the thread is finished.
23. 60°.
24. By adjusting the feed screw of the compound rest.
25. Because the tool is withdrawn by moving it toward the center or axis of the lathe.
26. Because the first cut is used only to determine if the lathe is set properly for the desired thread pitch.
27. The mating threaded part (nut).
28. Lard oil. (If lard oil is not available, any good cutting oil, or machine oil, may be used.)



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29. A small amount of powdered sulfur.
30. A hole may be drilled at the end of the thread, or a neck or groove may be cut around the shaft.

## CHAPTER 15

# INSPECTION, MAINTENANCE, AND REPAIR OF AUXILIARY EQUIPMENT

1. A good hydraulic fluid must have a low rate of expansion and be adequately viscous at 150° F.
2. To prevent small amounts of water and other foreign matter from entering the system.
3. At least every six months.
4. Keep the exposed surfaces covered with the prescribed compound or oil; construct protective guards over the exposed portions of the rams; and secure or remove loose gear.
5. About every six months.
6. Compression of brake linings.
7. Size of the installation, oil pressure, speed, and stroke.
8. Regular operation, proper lubrication, proper maintenance of all the units, and cleanliness of the fluid.
9. To prevent the accumulation of sludge, to aid in preventing corrosion, and to prevent the freezing of adjacent parts.
10. Oil from the high-pressure side may be escaping into the expansion tank, or the pressure control may be inoperative.
11. A hydraulic unit filled with flushing oil should be operated only under light load, and with the operating pressure as low as possible.
12. The packing will become hard and score the shaft.
13. Insufficient oil, leakage, obstructions, and improper adjustments.
14. Large leaks can usually be located with a pressure gage, while small leaks may require disassembly and visual inspection of the parts.
15. (1) Defective air valves resulting from wear and pounding of valves against seats, and dirty intake air, (2) defective air cylinder stuffing box.
16. Air cylinders may be poorly lubricated; piston-rod packing may be dry and binding; discharge valves may be leaking, or air-piston rings may be loose.
17. Because explosive vapors may collect in the compressor or air receiver.
18. The discharge air valve is defective.

19. Dirty intake air, excessive use or improper grade of cylinder oil, or excessively high air temperature resulting from faulty cooling.
20. Make certain that suction valves open toward, and discharge valves away from, the center of the cylinder.
21. Solder or fuse wire.
22. Sponge or woolen yarn does not pack down and stop the air flow.
23. To determine if there is any external corrosion or damage to flasks or piping.
24. Inspect all intake and compressor control lines for obstructions and foreign matter, and inspect the interior or exterior of the compressor.
25. Every three months.
26. (1) The siren should be installed as near a vertical position as possible, and (2) the air line should be thoroughly blown out and cleared before it is connected.
27. Daily.
28. Its impurities are different from those of ordinary boiler feed water, and cannot be controlled by the usual water-treatment methods.
29. Because a leak in this piping allows sea water to mix with the drains and can contaminate the boiler water in a very short time.
30. Water tube natural-circulation boilers.
31. Float type and electrode type feed water regulating and low water controls.

## CHAPTER 16

# NAVY REPAIR PROCEDURES

1. A repair ship performs maintenance functions beyond the capabilities of a ship's own facilities; a tender performs repair work, supplies parts, and renders other services to assigned ships.
2. AR.
3. To maintain a well-organized and efficiently operated repair department.
4. Assistant repair officer.
5. Diving and salvage officer.
6. BuShips, the forces afloat, and CNO.
7. Alterations affecting the military characteristics of the ship.
8. The type and ship serial numbers.
9. Alterations equivalent to repairs.
10. In the log room.
11. 2 weeks.

12. When outside assistance is needed, or at designated routine periods.
13. A restricted availability.
14. When a unit of auxiliary equipment, such as a small pump or motor, requires repairs. The unit(s) is detached and left for repair while the ship continues on its mission.
15. A work request is called a job order after it has been approved by the repair activity.
16. The ship's force.
17. To see that the job is neither delayed nor overlooked, and that it is satisfactorily completed at the end of the repair period.
18. Ship's personnel.
19. To see that all material conditions are satisfactory and that the equipment or machinery is in all respects ready for service.
20. To see that no phase of the ship's force maintenance work has been overlooked.
21. Type commander.
22. A shipyard to which a particular vessel is usually assigned by CNO for accomplishment of repairs and alterations.
23. 60 days.
24. CSMP.
25. BuShips.
26. SHIPALTS marked "ship's force" or "forces afloat."
27. The planning officer.
28. The planning officer, or his assistant.
29. Repair procedures, unsatisfactory work by yard personnel, and tests made by the shipyard.
30. The ship's progressman.
31. Each time it goes to the naval shipyard for a routine overhaul.
32. The Machinery History and CSMP should be checked to ensure that the detailed information concerning all sea valves is available.
33. The condition of the yoke, yoke rods, valve stem, and securing bolts, as well as the condition of the internal parts of the valve.
34. Whenever major repairs have been made on propulsion machinery by a naval shipyard.

## CHAPTER 17

# ENGINEERING MATERIALS AND SUPPLIES

1. General Stores Material, BuShips Controlled Material, and BuShips repair parts.
2. General Stores Material (GSM).
3. BuSandA.

4. Supply officer.
5. *BuShips Material Directory and Requisitioning Guide*, NavShips 250–550.
6. Once each year.
7. The incoming officer.
8. When they are being relieved or transferred.
9. At the beginning of the fiscal year.
10. Immediately upon the issuance or use of the repair part.
11. Engineer officer.
12. Engineering personnel; usually a leading petty officer.
13. In the same space as, or near, the machinery to which they pertain. In this case, the repair parts boxes are placed in specially made brackets, usually on bulkheads.
14. In the log room.
15. Repair parts boxes are identified by stamped or stenciled data, giving the number of the box and the name of machine or equipment for which the parts are supplied.
16. When the ship is placed in commission.
17. Priority C.
18. NavSandA Form 43, or the Not In-Excess Requisition.
19. In order to be able to properly write up a rough survey request.
20. In the division of the department having custody of the material or equipment to be surveyed.
21. Condition, cause, responsibility for the cause or condition, and recommendation.
22. When it has been approved by the engineer officer.
23. The surveying officer or the senior officer of the surveying board.
24. To the CO; or, if the survey was ordered by higher authority, to the officer ordering the survey.
25. They are forwarded to BuShips.
26. In the engineering log room.
27. BuShips.
28. Naval Stock Fund (NSF).
29. Appropriation Purchases Account (APA).
30. The appropriation of the bureau having material control of the item.

## CHAPTER 18

# ENGINEERING RECORDS AND REPORTS

1. In the machinery spaces.
2. A record of all pertinent data and repairs on each machinery unit, or pieces of equipment, aboard ship.
3. Unit Record Card.
4. Repair Record Card.

5. The card should be placed behind the Machinery History Card of the unit affected, with the tax extended above the top of the card.
6. At least 30 days prior to the commencement of the overhaul period.
7 In their relative order of priority.
8. The repair requests should accurately describe, in detail, existing conditions and the work which should be undertaken by the repair activity.
9. To the type commander or his authorized representative.
10. In the CSMP, on the Repair Record Card of the unit(s) affected.
11. In letter form submitted to BuShips via the type commander or other appropriate commanders.
12. The Engineering Log and the Engineer's Bell Book.
13. They should be overlined by a single line and initialed by the person making the original entry.
14. The throttleman.
15. The daily check-off list.
16. After each extended run, or after 10 days of intermittent service.
17. Machinery History Cards.
18. At least once each month, or more often if either fouling or disintegration is rapid.
19. Packing Chart.
20. A certified copy of the page is made for the ship's files.
21. In the *Navy Filing Manual.*
22. By standard Navy filing numbers.
23. Material Analysis Data and Repair Parts Usage Report.
24. To provide BuShips with data to be used in the analysis of ship performance and to afford a basis for design comparisons.
25. When they become 3 years old.
26. After they are 6 months old.

## CHAPTER 19

# FORMAL INSPECTIONS AND TRIALS

1. When his ship is required to furnish the inspecting party that will make an inspection of another ship.
2. Administrative inspection.
3. The engineer officer.
4. The type commander.
5. Operational readiness inspection.
6. To provide a medium for testing and evaluating the ability of the ship's divisions when operating under simulated combat conditions.

7. Surprise.
8. Verbal, when practicable.
9. When the inadequacy of procedure by ship's personnel results in the non-discovery of an imposed casualty.
10. Ship's personnel.
11. An emergency procedure is set up by the observing party and the ship's company.
12. The start of the battle problem, the problem time at regular intervals, the conclusion of the problem, and the restoration of casualties.
13. The general announcing system (1MC circuit).
14. A knowledge of existing excellencies by ship's personnel tends to increase morale as well as to indicate those factors that presently, at least, may receive less emphasis in the shipboard training program.
15. The critique and the observers' written reports.
16. The material inspection.
17. When it has a direct bearing on the material condition.
18. 50 percent.
19. The machinery, the electrical, and the hull condition sheets.
20. The ship's commanding and executive officers, heads of departments, and such other personnel as may be designated from the inspected ship, the Chief Inspector, and inspectors of each inspection group.
21. The material inspection is conducted by Forces Afloat, usually a sister ship, and the Board of Inspection and Survey inspection is conducted by a specially appointed board.
22. Every 3 to 5 years.
23. The Board of Inspection and Survey.
24. The builder's personnel.
25. Post-repair trials, full power trials, and economy trials.
26. To ensure that no material item will interfere with the successful operation of the ship at full power.
27. Because shallow water may cause excessive vibration, loss of speed, and overloading of the propulsion plant.
28. Economy and full power trials.
29. 4 hours.
30. The Chief Observer.
31. The Chief Observer.
32. Every half hour.
33. The designed boiler power.
34. The steam pressure and temperature will drop below normal values for that particular steaming condition.
35. To prevent the overloading of boilers.

# APPENDIX II

# QUALIFICATIONS FOR ADVANCEMENT IN RATING

## MACHINIST'S MATES (MM)

### RATING CODE NO. 3700

## General Service Rating

#### Scope

Machinist's mates operate, maintain, and make repairs to ship propulsion and auxiliary equipment such as steam propulsion machinery, shafts, propellers, evaporators, compressors, pumps, valves, oil purifiers, heat exchangers, governors, and reduction gears; maintain and make repairs to outside machinery such as steering engine, anchor windlass, cranes, elevators, food preparation and related utility equipment, and winches; operate, maintain, and repair refrigeration and air conditioning equipment; may perform duties in the generation, stowage, and transfer of the following industrial gases: Oxygen, carbon dioxide, nitrogen, and acetylene.

NOTE.—Personnel in the GENERAL SERVICE RATING will not be examined in industrial gas.

## Emergency Service Ratings

MACHINIST'S MATES L (General Machinist's Mates), Rating Code No. 3701 ---------------------------------------- MML

Operate, maintain, and make repairs to main propulsion and auxiliary machinery of steam-propelled vessels.

MACHINIST'S MATES R (Refrigeration Mechanics), Rating Code No. 3702 ---------------------------------------- MMR

Operate, maintain, and repair refrigeration and air conditioning equipment.

MACHINIST'S MATES G (Gas Generating Mechanics), Rating Code No. 3703 ---------------------------------------- MMG

Operate and maintain machinery for generating and compressing industrial gas and for charging compressed-gas containers.

## Navy Job Classifications and Codes

For specific Navy job classifications included with this rating and the applicable codes, see Manual of Navy Enlisted Classifications, NavPers 15105 (Revised), codes MM–4200 to MM–4299.

| Qualifications for Advancement in Rating | Applicable Rates | | | |
|---|---|---|---|---|
| | MM | MML | MMR | MMG |
| 100 PRACTICAL FACTORS | | | | |
| 101 OPERATIONAL | | | | |
| 1. Start, operate, stand watch on, and secure double- or triple-effect distilling plants | 3 | 3 | ---- | ---- |
| 2. Stand watch in steering engine room | 3 | 3 | ---- | ---- |
| 3. Use radiac instruments and perform monitoring operations on intake lines and evaporators | 3 | 3 | ---- | ---- |
| 4. Operate a $CO_2$ plant, refill $CO_2$ cylinders, and take gas analysis test during operation | ---- | ---- | ---- | 3 |
| 5. Operate compressors and motors and take gas analysis test on an oxygen plant and log readings on a $CO_2$ and acetylene plant | ---- | ---- | ---- | 3 |
| 6. Operate and stand watch on $CO_2$ and oxygen transfer equipment | ---- | ---- | ---- | 3 |
| 7. When warming up main steam-propulsion machinery fitted with reduction gear and motor-driven turning gear: | | | | |
| a. Measure turbine clearances where indicators are installed. Specify that they are cold readings | C | C | ---- | ---- |
| b. Back all throttle valves off seat and reseat lightly by hand | 1 | 1 | ---- | ---- |
| c. Check for water in lubricating oil and use lubricating oil purifier if necessary | 2 | 2 | ---- | ---- |
| d. Heat lubricating oil in sump tank to 90° F. and secure steam to heating coils | 2 | 2 | ---- | ---- |
| e. Clean all oil and bilge strainers | 3 | 3 | ---- | ---- |
| f. Ease up on stern tube gland, allowing a small amount of water to leak through the gland | 3 | 3 | ---- | ---- |
| g. Line up lubricating oil system | 2 | 2 | ---- | ---- |
| h. Start lubricating oil pump | 2 | 2 | ---- | ---- |
| i. See that oil is delivered to turbines, reduction gears, and thrust bearings. Inspect for leaks | 3 | 3 | ---- | ---- |

| Qualifications for Advancement in Rating | Applicable Rates | | | |
| --- | --- | --- | --- | --- |
| | MM | MML | MMR | MMG |
| j. Open all drain valves on main steam line | 3 | 3 | ----- | ----- |
| k. Test low-pressure lubricating oil alarm system | 2 | 2 | ----- | ----- |
| l. Test stand-by lubricating oil pump | 2 | 2 | ----- | ----- |
| m. Obtain permission from bridge and start motor-driven turning gear and jack over main engine | 1 | 1 | ----- | ----- |
| n. Open main injection and overboard discharge valves | 3 | 3 | ----- | ----- |
| o. Start main circulator pump | 2 | 2 | ----- | ----- |
| p. Start main condensate pump and recirculate water | 2 | 2 | ----- | ----- |
| q. Cut in gland seal on turbine | 2 | 2 | ----- | ----- |
| r. Start second stage air ejector; build up vacuum on main condenser | 1 | 1 | ----- | ----- |
| s. Vent main condenser to insure that condenser is not air bound | 3 | 3 | ----- | ----- |
| t. Open all auxiliary low-pressure drains to main condenser. Secure auxiliary condenser and cut auxiliary exhaust steam not used elsewhere into main condenser | 3 | 3 | ----- | ----- |
| u. Line up system and recirculate water through deaerating tank | 1 | 1 | ----- | ----- |
| v. Open drains to whistle and siren | 3 | 3 | ----- | ----- |
| w. Cut in steam to whistle and siren | 3 | 3 | ----- | ----- |
| x. Warm up main feed pump and booster pump | 1 | 1 | ----- | ----- |
| y. Test engine telegraph | 1 | 1 | ----- | ----- |
| z. Take and log counter readings | 1 | 1 | ----- | ----- |
| aa. Put main feed pumps on line | 1 | 1 | ----- | ----- |
| bb. Open bulkhead stops to throttle or nozzle control valves | 2 | 2 | ----- | ----- |
| cc. Close throttle bypasses and warming-up valves | 1 | 1 | ----- | ----- |
| dd. Obtain permission from bridge and turn main engines | 1 | 1 | ----- | ----- |
| ee. Disengage motor-driven turning gear | 1 | 1 | ----- | ----- |

| Qualifications for Advancement in Rating | Applicable Rates | | | |
|---|---|---|---|---|
| | MM | MML | MMR | MMG |
| ff. Obtain permission from bridge and spin main engines | 1 | 1 | ----- | ----- |
| gg. Take and record hot turbine clearances | C | C | ----- | ----- |
| hh. Start first-stage air ejector; build vacuum to maximum obtainable | 1 | 1 | ----- | ----- |
| ii. Line up main lubricating oil cooler | 3 | 3 | ----- | ----- |
| jj. Make final inspection preparatory to reporting engine room ready to answer all bells | C | C | ----- | ----- |
| 8. When securing main steam propulsion machinery fitted with reduction gears and motor-driven turning gear: | | | | |
| a. Secure throttle valves | 2 | 2 | ----- | ----- |
| b. Rotate turbine rotors with shaft turning gear | 1 | 1 | ----- | ----- |
| c. Maintain lubricating oil pressure in all bearings during rotation | 2 | 2 | ----- | ----- |
| d. Secure main steam line and drain thoroughly before securing drains | 3 | 3 | ----- | ----- |
| e. Open turbine drains | 3 | 3 | ----- | ----- |
| f. Secure steam to first-stage air ejectors | 1 | 1 | ----- | ----- |
| g. Start auxiliary condenser and cut auxiliary exhaust and low-pressure drains into it | 1 | 1 | ----- | ----- |
| h. Start auxiliary and secure main feed pump | 1 | 1 | ----- | ----- |
| i. Continue operating turning gear and circulating lubricating oil through the system for at least 1 hour after gland steam has been secured | 1 | 1 | ----- | ----- |
| j. Secure steam to second-stage air ejectors | 1 | 1 | ----- | ----- |
| k. Secure gland seal steam and condensate pumps | 2 | 2 | ----- | ----- |
| l. Complete securing of air ejectors and break vacuum through air ejector suction | 1 | 1 | ----- | ----- |
| m. Secure main circulating pumps | 2 | 2 | ----- | ----- |

| Qualifications for Advancement in Rating | MM | MML | MMR | MMG |
|---|---|---|---|---|
| n. Close main injection and overboard discharge valves | 3 | 3 | ----- | ----- |
| o. Inspect to insure that all root, throttle, exhaust, and drain valves of all auxiliaries not in use are closed | 2 | 2 | ----- | ----- |
| p. Drain waterside of oil coolers to bilges | 3 | 3 | ----- | ----- |
| q. Close turbine and steam line drains after 24 hours | 3 | 3 | ----- | ----- |
| 9. Start, operate, stand watch on, and secure refrigeration and air conditioning systems | 2 | ----- | 3 | ----- |
| 10. Start, operate, and secure Diesel generator used for power supply to oxygen plants | ----- | ----- | ----- | 2 |
| 11. Start, operate, and secure Diesel generator used for an acetylene plant | ----- | ----- | ----- | 2 |
| 12. Operate engine lathe for cutting threads and tapers and for plain turning | 1 | 1 | ----- | ----- |
| 13. Start, operate, and secure an oxygen plant | ----- | ----- | ----- | 1 |
| 14. Select a site and set up industrial gas generating, stowage, and transfer equipment | ----- | ----- | ----- | C |
| 102 MAINTENANCE AND/OR REPAIR | | | | |
| 1. Change strainers and clean filters on gas generating equipment | ----- | ----- | ----- | 3 |
| 2. Lubricate all pumps and compressors used in gas generating plants | ----- | ----- | ----- | 3 |
| 3. Remove scale from evaporator tubes by cold shocking | 3 | 3 | ----- | ----- |
| 4. Spot and grind in valves | 3 | 3 | 3 | 3 |
| 5. Renew bonnet gaskets in valves | 3 | 3 | 3 | 3 |
| 6. Repack stuffing boxes on centrifugal pumps with specified packing | 3 | 3 | 3 | 3 |
| 7. Replace zinc plates in main and auxiliary condensers | 3 | 3 | ----- | ----- |
| 8. Clean salt-water side of main and auxiliary condensers | 3 | 3 | 3 | ----- |

| Qualifications for Advancement in Rating | Applicable Rates | | | |
|---|---|---|---|---|
| | MM | MML | MMR | MMG |
| 9. Remove drying agent from adsorbers on an oxygen plant and refill | ---- | ----- | ----- | 2 |
| 10. Repack valves using specified type of packing on gas generating equipment | ---- | ----- | ----- | 2 |
| 11. Change oil and lubricate Diesel generators used for power supply on gas generating plants | ---- | ----- | ----- | 2 |
| 12. Make minor repairs to insulation or lagging on piping | 2 | 2 | 2 | 2 |
| 13. Remove scale from evaporator tubes chemically | 2 | 2 | ----- | ----- |
| 14. Fit piston rings to steam cylinder of reciprocating pumps | 2 | 2 | ----- | ----- |
| 15. Spot-in slide valve on steam chest of reciprocating pump | 2 | 2 | ----- | ----- |
| 16. Test and renew suction and discharge valves on air compressors | 2 | 2 | 2 | 2 |
| 17. Use dial indicators, micrometers, depth gages and inside-outside vernier calipers to take clearances on journals and bearings | 2 | 2 | 2 | 2 |
| 18. Check for noncondensible gases and pump down refrigerant systems | 2 | ----- | 2 | 2 |
| 19. Use halide torch on refrigeration or air conditioning equipment to test for leaks | 2 | ----- | 2 | 2 |
| 20. Clean air ejector steam strainers | 2 | 2 | ----- | ----- |
| 21. Clean inner and after air ejector condenser tubes | 2 | 2 | ----- | ----- |
| 22. Reface valve seats and discs | 2 | 2 | 2 | 2 |
| 23. Replace regulating valve diaphragms | 2 | 2 | 2 | 2 |
| 24. Repack high-pressure valves | 2 | 2 | 2 | 2 |
| 25. Spot in and replace bearings on centrifugal pumps | 2 | 2 | 2 | 2 |
| 26. Replace oil seals on refrigeration compressors | 1 | ----- | 2 | 2 |
| 27. Inspect, dry out, and recondition oxygen and $CO_2$ cylinders | ---- | ----- | ----- | 1 |
| 28. Dehydrate, test, and recharge refrigeration systems | 1 | ----- | 1 | 1 |

## Qualifications for Advancement in Rating

| | Applicable Rates | | | |
|---|---|---|---|---|
| | MM | MML | MMR | MMG |
| 29. Inspect and recondition acetylene cylinders | ---- | ---- | ---- | 1 |
| 30. Check alinement of couplings and determine clearances of bearings on pumps for gas generating equipment | ---- | ---- | ---- | 1 |
| 31. Set all relief valves to required pressure | 1 | 1 | 1 | 1 |
| 32. Repair centrifugal pump pressure regulators | 1 | 1 | 1 | 1 |
| 33. Spot in or replace carbon packing rings on centrifugal pumps | 1 | 1 | ---- | ---- |
| 34. Take clearances and replace wearing rings on centrifugal pumps | 1 | 1 | 1 | 1 |
| 35. Check for alinement of centrifugal pump driving unit | 1 | 1 | 1 | 1 |
| 36. Make air and soapsuds test on main and auxiliary condenser | 1 | 1 | ---- | ---- |
| 37. Replace worn or broken reciprocating pump piston rings | 1 | 1 | ---- | ---- |
| 38. Aline upper and lower cylinders of reciprocating pumps | 1 | 1 | ---- | ---- |
| 39. Adjust slide valve on steam and exhaust side of reciprocating pumps | 1 | 1 | ---- | ---- |
| 40. Adjust air ejector steam reducing valve | 1 | 1 | ---- | ---- |
| 41. Adjust air ejector thermostatically controlled recirculating valves | 1 | 1 | ---- | ---- |
| 42. Adjust tappets for proper piston stroke on reciprocating pumps | 1 | 1 | ---- | ---- |
| 43. Grind in or replace valve discs and seats in water end of reciprocating pump | 1 | 1 | ---- | ---- |
| 44. Renew weak or broken valve springs in water end of reciprocating pump | 1 | 1 | ---- | ---- |
| 45. Remove scores from cylinder wall of water end and steam end of reciprocating pump | 1 | 1 | ---- | ---- |
| 46. Renew packing rings in water end of reciprocating pump | 1 | 1 | ---- | ---- |
| 47. Test evaporator tubes hydrostatically for leaks | 1 | 1 | ---- | ---- |
| 48. Make repairs to pumps and compressors on gas generating equipment | ---- | ---- | ---- | C |
| 49. Plug and replace condenser tubes | C | C | C | C |

| Qualifications for Advancement in Rating | MM | MML | MMR | MMG |
|---|---|---|---|---|
| 50. Set hydraulic speed limiting governor on centrifugal pumps | C | C | ---- | ---- |
| 51. Set hydraulic pressure governor on centrifugal pumps | C | C | ---- | ---- |
| 52. Set geared centrifugal fly-ball type governor on centrifugal pumps | C | C | ---- | ---- |
| 53. Clean first- and second-stage air ejector nozzles and diffusers | C | C | ---- | ---- |
| 54. Take main turbine and reduction gear bearing clearances, thrust clearances, and turbine blade clearances | C | C | ---- | ---- |
| 103 ADMINISTRATIVE AND/OR CLERICAL | | | | |
| 1. Locate and use appropriate sections of the BuShips Manual, manufacturers' instruction books, mechanical drawings, and handbooks to obtain data when repairing machinery | 1 | 1 | 1 | 1 |
| 2. Supervise and train personnel in operation, maintenance, and repair of: | | | | |
| a. All engine room equipment | C | C | ---- | ---- |
| b. Refrigeration and air conditioning equipment | C | ---- | C | ---- |
| c. Gas generating equipment | ---- | ---- | ---- | C |
| 3. Take charge of an engine room watch on steam-propelled vessel | C | C | ---- | ---- |
| 4. Take charge of a watch on gas generating equipment | ---- | ---- | ---- | C |
| 5. Keep engine room records and prepare naval shipyard and tender work requests | C | C | C | C |
| 6. Estimate time and material needed for repair of auxiliary and main propulsion machinery | C | C | ---- | ---- |
| 200 EXAMINATION SUBJECTS | | | | |
| 201 OPERATIONAL | | | | |
| 1. Safety precautions involved in performing tasks appropriate to applicable rates listed under 100 Practical Factors | ---- | ---- | ---- | ---- |
| 2. First-aid procedures in instances of exposure to refrigerants in liquid or gaseous states and in instances of electrical shock and heat exhaustion | 3 | 3 | 3 | 3 |

Applicable Rates: MM, MML, MMR, MMG

| Qualifications for Advancement in Rating | Applicable Rates | | | |
|---|---|---|---|---|
| | MM | MML | MMR | MMG |
| 3. Safety precautions to be observed when working on shipboard machinery, taking on fuel, and moving or lifting heavy objects | 3 | 3 | 3 | 3 |
| 4. Safety precautions to be observed when generating, transferring, stowing, and handling industrial gases | ---- | ---- | ---- | 3 |
| 5. Uses and characteristics of industrial gases and their identification by standard markings on containers | 3 | 3 | 3 | 3 |
| 6. Purpose and principles of operation of: | | | | |
| a. Reduction gears | 3 | 3 | ---- | ---- |
| b. Double- and triple-effect distilling plants | 3 | 3 | ---- | ---- |
| c. Compressors | 3 | 3 | 3 | 3 |
| d. Main and auxiliary condensers | 3 | 3 | ---- | ---- |
| e. Lubricating oil purifiers | 3 | 3 | ---- | ---- |
| f. Air ejectors | 2 | 2 | ---- | ---- |
| g. Rotary, reciprocating, and centrifugal pumps | 2 | 2 | 2 | 2 |
| h. High- and low-pressure turbines | 2 | 2 | ---- | ---- |
| i. Turning gears | 2 | 2 | ---- | ---- |
| j. Steering engines | 2 | 2 | ---- | ---- |
| k. Relief valves | 2 | 2 | 2 | 2 |
| l. Turbogenerators | 2 | 2 | ---- | ---- |
| 7. Construction and operation of Freon-12 type of refrigerating units. Characteristics of refrigerants | 2 | ---- | 3 | 3 |
| 8. Power, fuel, water, chemicals, and other consumable materials required for operation of gas generating plants | ---- | ---- | ---- | 2 |
| 9. Principles of operation of oxygen, $CO_2$, and acetylene generating plants and associated equipment | ---- | ---- | ---- | 2 |
| 10. Tests required by the Interstate Commerce Commission when shipping industrial gas containers | ---- | ---- | ---- | 2 |
| 11. Purpose and principles of operation of: | | | | |
| a. Refrigeration expansion valves | 1 | ---- | 2 | 2 |
| b. Deaerating tank | 1 | 1 | ---- | ---- |
| c. Thrust bearings | 1 | 1 | ---- | ---- |

| Qualifications for Advancement in Rating | Applicable Rates | | | |
|---|---|---|---|---|
| | MM | MML | MMR | MMG |
| d. Centrifugal pump governors | 1 | 1 | ----- | ----- |
| e. Gland sealing system | 1 | 1 | ----- | ----- |
| 12. Methods and procedures for starting and securing steam turbine generator | 1 | 1 | ----- | ----- |
| 13. Safety factors to be considered in selection of a site, and in installation of equipment, for oxygen, $CO_2$, and acetylene generating plants | ----- | ----- | ----- | C |
| 202 MAINTENANCE AND/OR REPAIR | | | | |
| 1. Chloride limits and frequency of tests on the following: | | | | |
| a. Make-up feed water | 3 | 3 | ----- | ----- |
| b. Distiller discharge to reserve feed tanks | 3 | 3 | ----- | ----- |
| c. Main and auxiliary condensers | 3 | 3 | ----- | ----- |
| d. Reserve feed tanks | 3 | 3 | ----- | ----- |
| e. Deaerating and surge tanks on main feed line | 3 | 3 | ----- | ----- |
| 2. Purpose and procedures for cold shocking evaporators | 3 | 3 | ----- | ----- |
| 3. Procedures to be followed when: | | | | |
| a. Changing and cleaning filters on gas generating equipment | ----- | ----- | ----- | 3 |
| b. Lubricating gas generating equipment | ----- | ----- | ----- | 3 |
| c. Repacking stuffing boxes on centrifugal pumps | 3 | 3 | 3 | 3 |
| d. Replacing zincs in main and auxiliary condensers | 3 | 3 | 3 | 3 |
| e. Removing drying agent from adsorbers on oxygen plant | ----- | ----- | ----- | 2 |
| f. Removing scale from evaporator tubes | 2 | 2 | ----- | ----- |
| g. Fitting piston rings to steam cylinder of reciprocating pumps | 2 | 2 | ----- | ----- |
| h. Spotting-in slide valves on steam chest of reciprocating pumps | 2 | 2 | ----- | ----- |
| i. Testing and renewing suction and discharge valves on compressors | 2 | 2 | 2 | 2 |
| j. Spotting-in and replacing bearings of centrifugal pumps | 2 | 2 | 2 | 2 |

| Qualifications for Advancement in Rating | MM | MML | MMR | MMG |
|---|---|---|---|---|
| k. Renewing ram packing on hydraulic steering gears and elevators | 2 | 2 | ----- | ----- |
| l. Changing seals and gaskets on hydraulic equipment | 2 | 2 | ----- | ----- |
| m. Inspecting and adjusting food preparation and dishwashing machinery | 2 | 2 | ----- | ----- |
| n. Inspecting and adjusting safety devices and operating gear on laundry machinery | 2 | 2 | ----- | ----- |
| o. Dehydrating, testing, and recharging of refrigeration systems | 1 | ----- | 2 | 2 |
| p. Replacing oil seals on refrigeration compressors | 1 | ----- | 2 | 2 |
| 4. Methods of testing evaporators and condensers for salt water leaks | 2 | 2 | 2 | 2 |
| 5. Procedures to be followed when these casualties occur: | | | | |
| a. Lubricating oil cooler tube carries away | 2 | 2 | ----- | ----- |
| b. Loss of, or low, lubricating oil pressure | 2 | 2 | ----- | ----- |
| c. Leak in main condenser | 2 | 2 | ----- | ----- |
| d. Failure of cooling water to auxiliaries | 2 | 2 | ----- | ----- |
| e. Loss of, or low, main feed booster pressure | 2 | 2 | ----- | ----- |
| f. Overheated bearings | 2 | 2 | ----- | ----- |
| g. Loss of main feed pressure | 2 | 2 | ----- | ----- |
| h. High- or low-water in deaerating tank | 2 | 2 | ----- | ----- |
| i. Unusual noise from pump end of main feed pump when starting | 2 | 2 | ----- | ----- |
| j. Jammed throttle ahead or astern | 2 | 2 | ----- | ----- |
| k. High oil level in reduction gear casing | 1 | 1 | ----- | ----- |
| l. Unusual noise in reduction gear | 1 | 1 | ----- | ----- |
| m. Metallic noise emanating from turbine | 1 | 1 | ----- | ----- |
| n. Loss of steam pressure in engine room | 1 | 1 | ----- | ----- |
| o. Locking and unlocking shaft under way | 1 | 1 | ----- | ----- |
| p. Turbine begins to vibrate | 1 | 1 | ----- | ----- |
| q. Loss of vacuum | 1 | 1 | ----- | ----- |

| | Applicable Rates | | | |
|---|---|---|---|---|
| | MM | MML | MMR | MMG |
| r. Empty feed bottom for make-up feed | 1 | 1 | ----- | ----- |
| s. Loss of power steering | 1 | 1 | ----- | ----- |
| 6. Lubricant requirements, and precautions when handling dehydrated oils for refrigerant systems | 1 | ----- | 2 | 2 |
| 7. Methods of fitting carbon packing rings to turbines | 2 | 2 | ----- | ----- |
| 8. Procedures to be followed when: | | | | |
| a. Inspecting and reconditioning oxygen, $CO_2$, and acetylene cylinders | ---- | ----- | ----- | 1 |
| b. Checking alinement of couplings and determining clearances of bearings on pumps for gas generating equipment | ---- | ----- | ----- | 1 |
| c. Setting relief valves | 1 | 1 | 1 | 1 |
| d. Repairing centrifugal pump pressure regulators | 1 | 1 | 1 | 1 |
| e. Taking clearances and replacing wearing rings on centrifugal pumps | 1 | 1 | 1 | 1 |
| f. Checking alinement of centrifugal-pump driving unit | 1 | 1 | ----- | ----- |
| g. Replacing worn and broken reciprocating-pump piston rings | 1 | 1 | ----- | ---- |
| h. Adjusting tappets on slide gear of reciprocating pumps | 1 | 1 | ----- | ----- |
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U. S. GOVERNMENT PRINTING OFFICE: 1955 O—297637

For sale by the Superintendent of Documents, U. S. Government Printing Office
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